

## PATENT COOPERATION TREATY

PCT

**NOTIFICATION OF ELECTION**  
(PCT Rule 61.2)

## From the INTERNATIONAL BUREAU

To:

Assistant Commissioner for Patents  
United States Patent and Trademark  
Office  
Box PCT  
Washington, D.C.20231  
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 04 October 2000 (04.10.00)	in its capacity as elected Office
International application No. PCT/GB00/00323	Applicant's or agent's file reference P23140A/VSL/CLF/PPP
International filing date (day/month/year) 07 February 2000 (07.02.00)	Priority date (day/month/year) 05 February 1999 (05.02.99)
<b>Applicant</b> DA SILVA MARQUES, Paulo, Vicente et al	

1. The designated Office is hereby notified of its election made:

in the demand filed with the International Preliminary Examining Authority on:

04 September 2000 (04.09.00)

in a notice effecting later election filed with the International Bureau on:

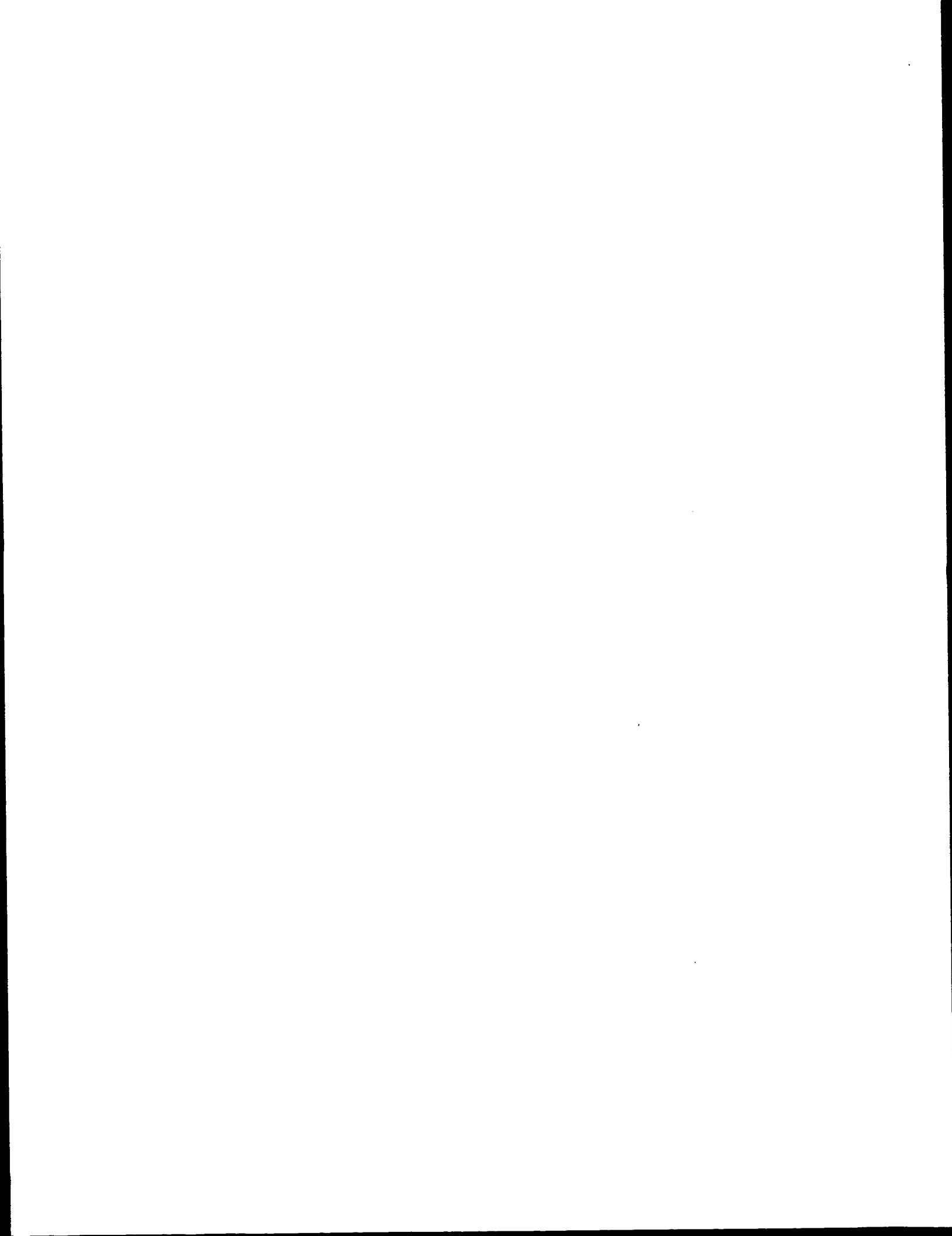
## 2. The election was

1

was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

<p><b>The International Bureau of WIPO</b>  <b>34, chemin des Colombettes</b>  <b>1211 Geneva 20, Switzerland</b></p>	<p><b>Authorized officer</b>  <b>Zakaria EL KHODARY</b></p>
<p>Facsimile No.: (41-22) 740.14.35</p>	<p>Telephone No.: (41-22) 338.83.38</p>



## INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference <b>P23140A/VSL/CLF/PPP</b>	<b>FOR FURTHER ACTION</b> see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. <b>PCT/GB 00/ 00323</b>	International filing date (day/month/year) <b>07/02/2000</b>	(Earliest) Priority Date (day/month/year) <b>05/02/1999</b>
Applicant <b>THE UNIVERSITY COURT OF THE UNIVERSITY OF et al.</b>		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 4 sheets.

It is also accompanied by a copy of each prior art document cited in this report.

**1. Basis of the report**

a. With regard to the language, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international search was carried out on the basis of the sequence listing :

contained in the international application in written form.

filed together with the international application in computer readable form.

furnished subsequently to this Authority in written form.

furnished subsequently to this Authority in computer readable form.

the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2.  Certain claims were found unsearchable (See Box I).

3.  Unity of invention is lacking (see Box II).

4. With regard to the title,

the text is approved as submitted by the applicant.

the text has been established by this Authority to read as follows:

5. With regard to the abstract,

the text is approved as submitted by the applicant.

the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the drawings to be published with the abstract is Figure No.

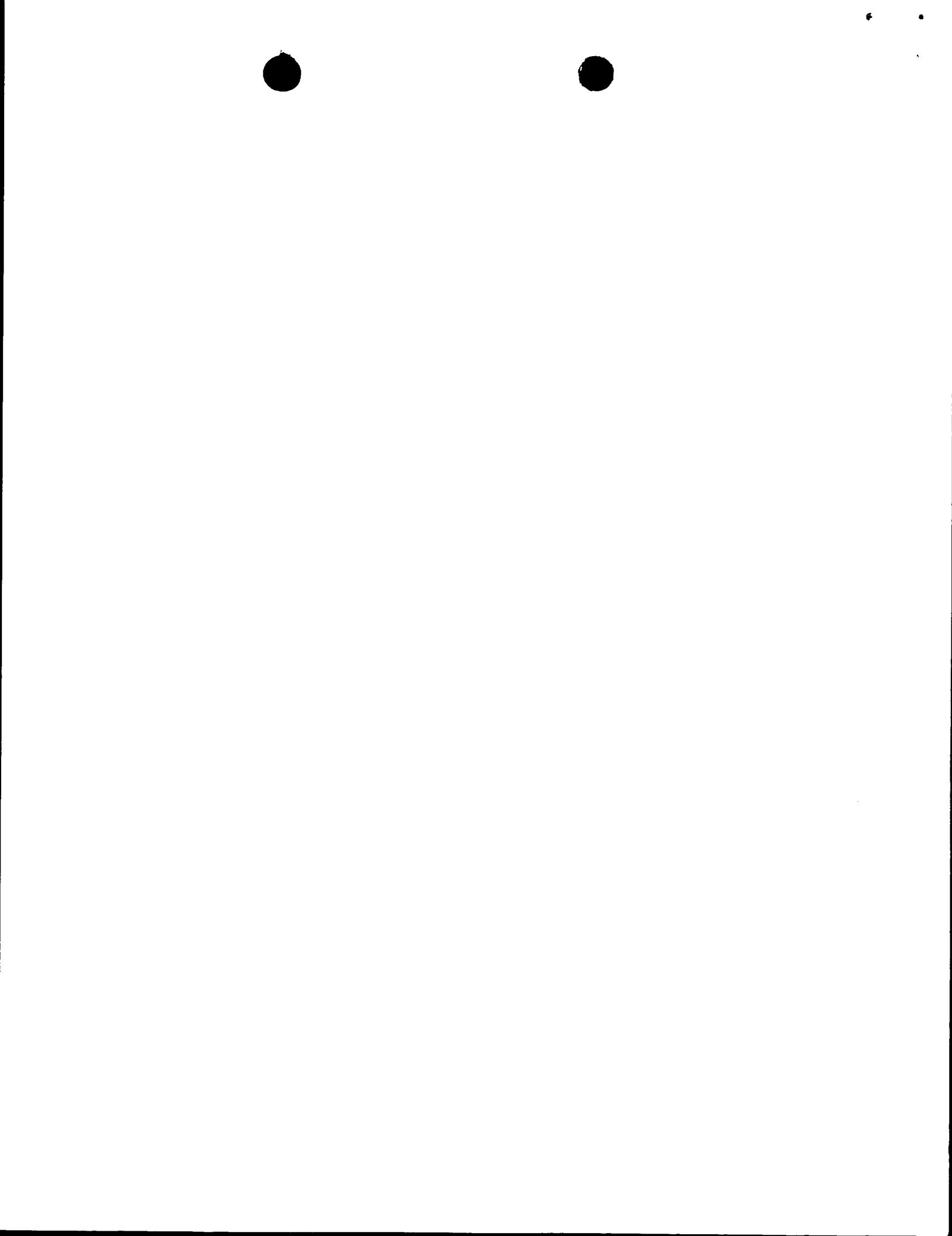
as suggested by the applicant.

because the applicant failed to suggest a figure.

because this figure better characterizes the invention.

2a, 2b

None of the figures.



A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 G02B6/132 H01S3

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 G02B H01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category <sup>o</sup>	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 206 925 A (KAMOSHIDA TOSHIKAZU ET AL) 27 April 1993 (1993-04-27) abstract; figures 1,3,4A-4D,8 column 1, line 51 -column 2, line 10 column 3, line 1 - line 19 column 3, line 38 - line 43 column 6, line 52 -column 7, line 21 column 8, line 7 - line 58 column 8, line 60 -column 9, line 25 column 10, line 10 - line 40 column 11, line 24 - line 29 ---	1-61, 82-85
X	US 5 303 319 A (FORD CAROL M ET AL) 12 April 1994 (1994-04-12) abstract; figures 3,4 column 2, line 10 - line 38 column 3, line 29 -column 4, line 43 --- -/-	1,30, 82-85

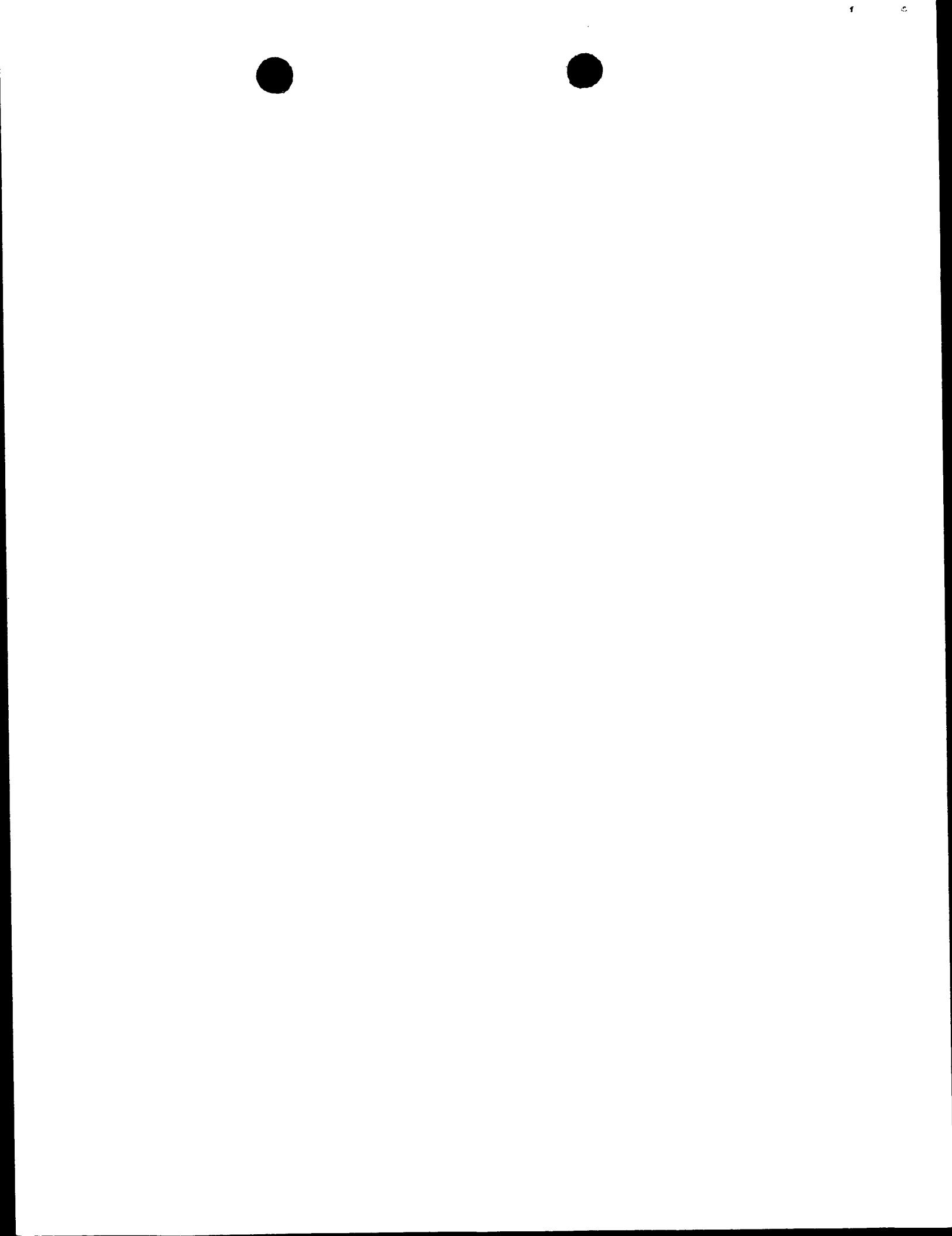
 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

## ° Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 May 2000	20.07.00
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer  Jakober, F



## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 890 850 A (LUCENT TECHNOLOGIES INC) 13 January 1999 (1999-01-13) abstract; figure 9 column 7, line 18 - line 41 ----	1,30, 82-85
A	EP 0 867 985 A (TNO) 30 September 1998 (1998-09-30) abstract page 3, line 20 - line 24 page 4, line 54 -page 5, line 27 page 5; table 1 -----	1-61



# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/GB 00/00323

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.: because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
  
3.  Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet(s)

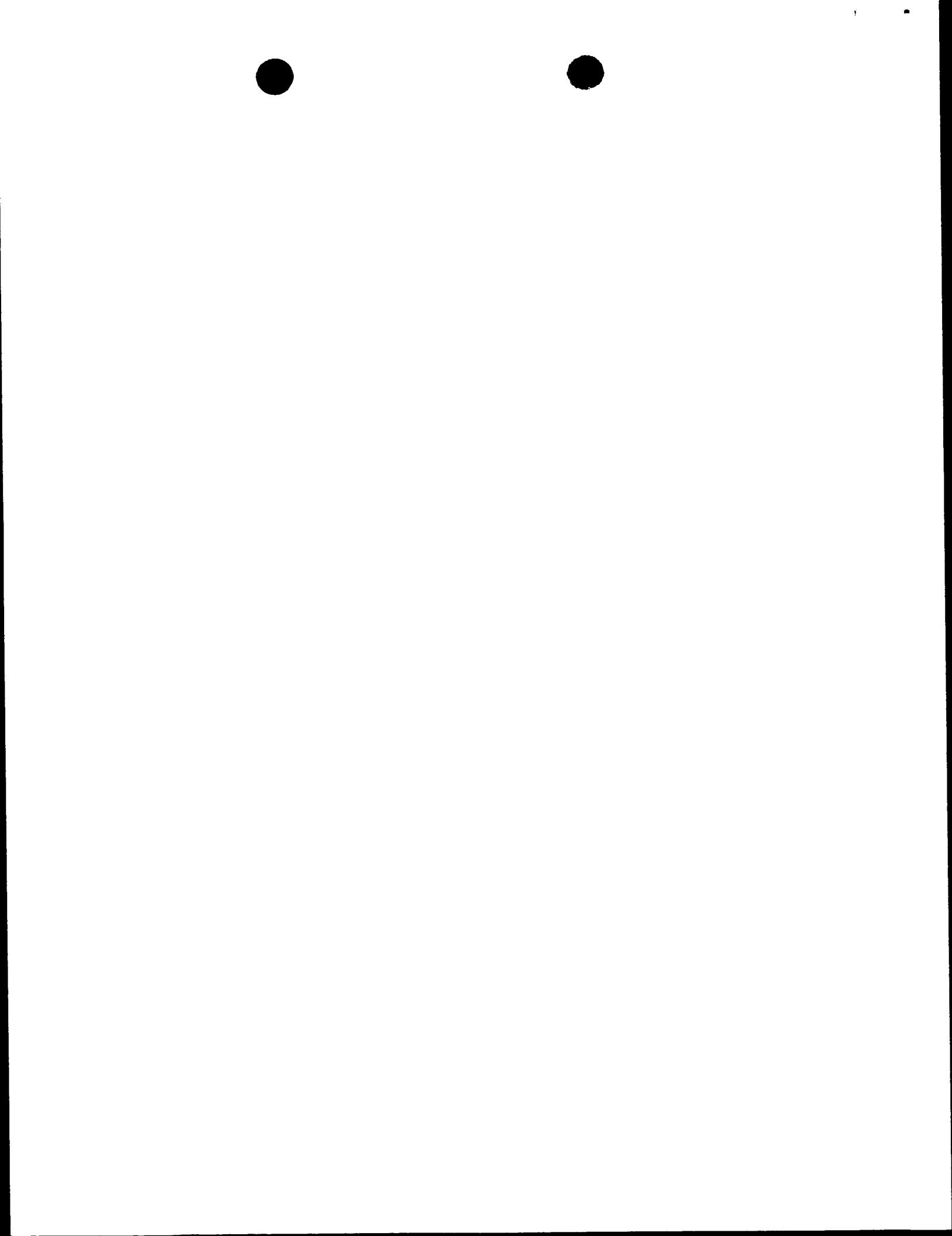
1.  As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
  
2.  As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
  
3.  As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
  
4.  No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-61,82-85

### Remark on Protest

The additional search fees were accompanied by the applicant's protest.

No protest accompanied the payment of additional search fees.



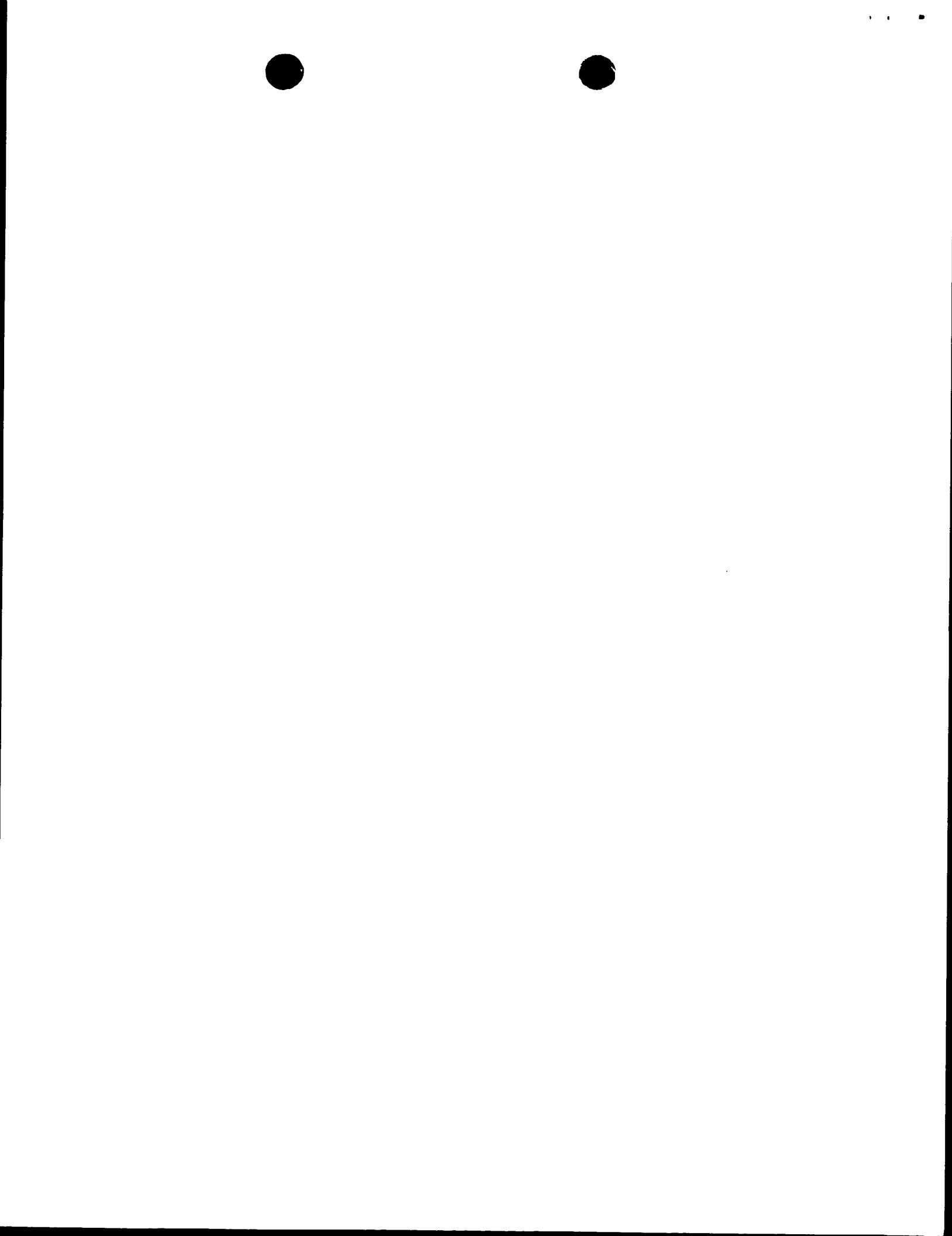
FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

1. Claims: 1-61,82-85

An optical waveguide comprising a buffer layer including a thermally oxidised layer.

2. Claims: 62-81

A laser waveguide comprising a grating formed in the waveguide core.



## INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 00/00323

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US 5206925	A 27-04-1993	JP 2755471	B	20-05-1998
		JP 4060618	A	26-02-1992
		CA 2040527	A,C	30-12-1991
		DE 4120054	A	02-01-1992
		GB 2245984	A,B	15-01-1992
US 5303319	A 12-04-1994	NONE		
EP 0890850	A 13-01-1999	US 6003222	A	21-12-1999
		JP 11084156	A	26-03-1999
EP 0867985	A 30-09-1998	JP 11038242	A	12-02-1999
		US 5982973	A	09-11-1999

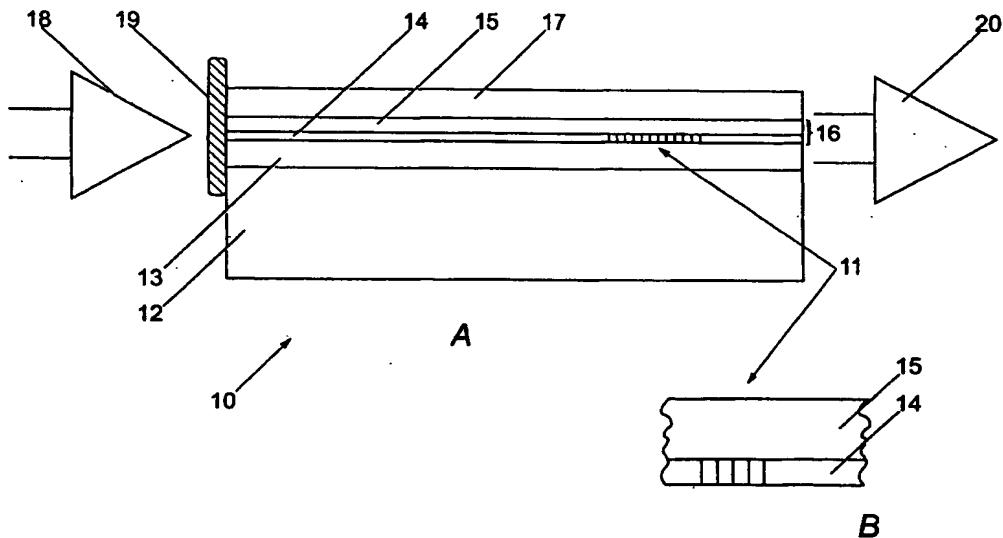




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

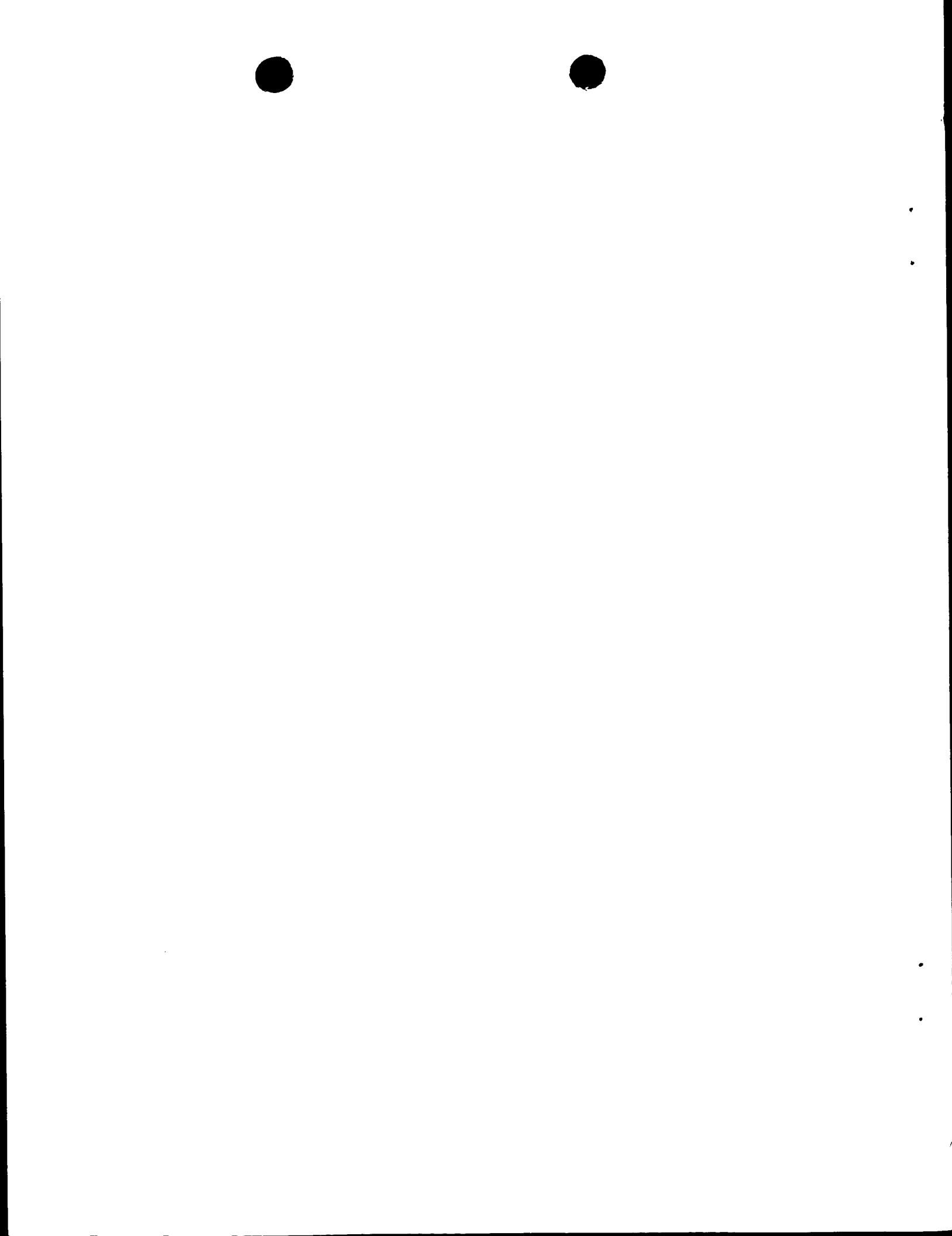
(51) International Patent Classification 7 : <b>G02B 6/132, H01S 3/063</b>		A1	(11) International Publication Number: <b>WO 00/46619</b> (43) International Publication Date: 10 August 2000 (10.08.00)
(21) International Application Number: <b>PCT/GB00/00323</b>			(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
(22) International Filing Date: 7 February 2000 (07.02.00)			
(30) Priority Data: 9902477.0 5 February 1999 (05.02.99) GB			
(71) Applicant (for all designated States except US): THE UNIVERSITY COURT OF THE UNIVERSITY OF GLASGOW [GB/GB]; University Avenue, Glasgow G12 8QQ (GB).			
(72) Inventors; and			Published
(75) Inventors/Applicants (for US only): DA SILVA MARQUES, Paulo, Vicente [PT/PT]; Rua da Vitoria, 405, P-4050 Porto (PT). BONAR, James, Ronald [GB/GB]; 47 Brodie Park Avenue, Paisley PA2 6JA (GB). AITCHISON, James, Stewart [GB/GB]; 127 Dowanhill Street, Glasgow G12 9DN (GB). PAIS PEREIRA LEITE, Antonio, Manuel [PT/PT]; Apt. 15, Rua Alfredo Keil, 243, P-4150 Porto (PT).			With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.
(74) Agent: MURGITROYD & COMPANY; 373 Scotland Street, Glasgow G5 8QA (GB).			

(54) Title: OPTICAL WAVEGUIDE WITH MULTIPLE CORE LAYERS AND METHOD OF FABRICATION THEREOF



## (57) Abstract

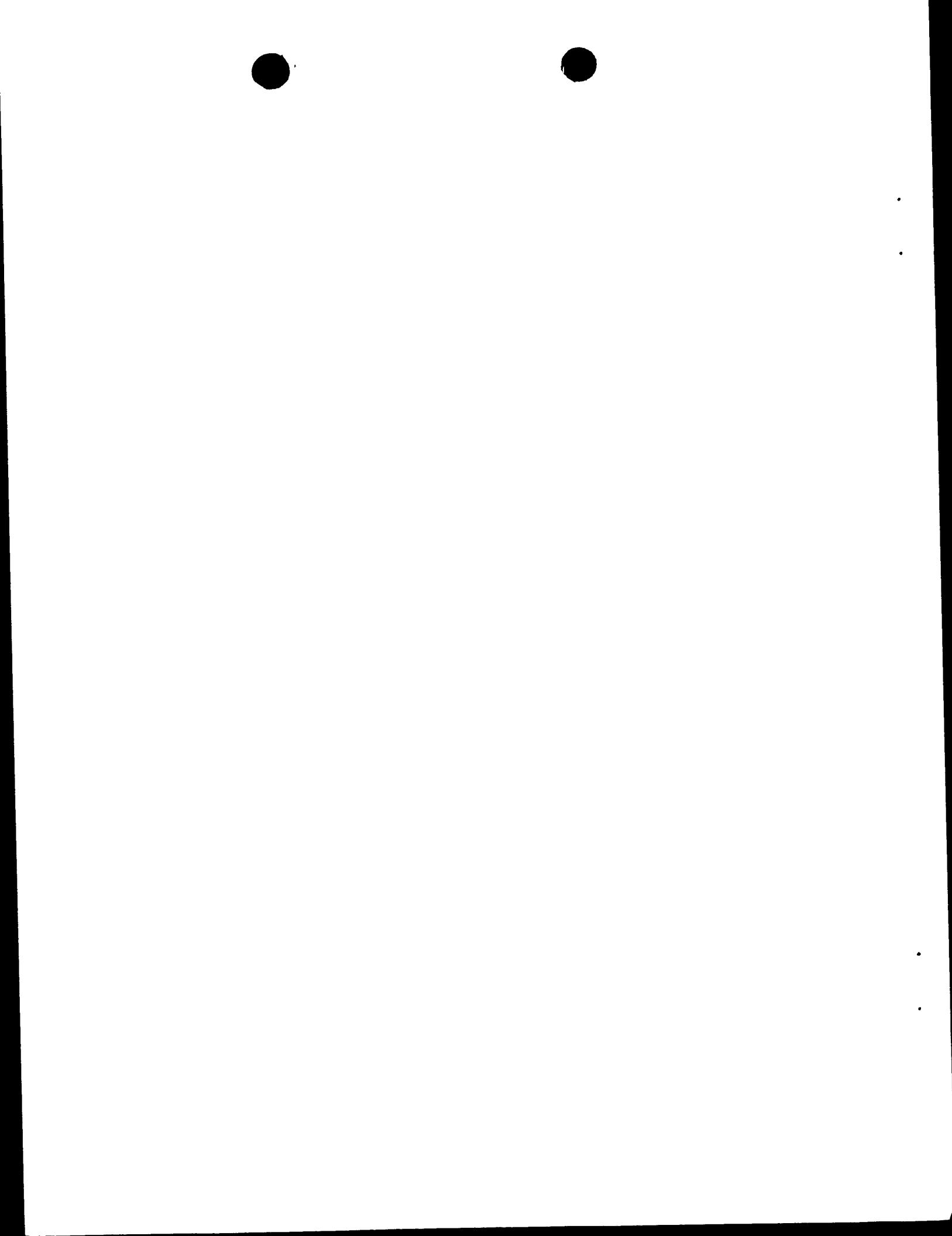
An optical waveguide with multiple core layers for transmitting an optical signal comprises a substrate; an intermediate layer formed on said substrate; a waveguide core formed on said intermediate layer; and an upper cladding layer embedding said waveguide core. The waveguide core comprises a first core layer formed on said intermediate layer and a second core layer formed on said first core layer. The first core layer has photosensitive properties and the second core layer has optical gain properties.



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DK	Denmark	LR	Liberia	SG	Singapore		



1       OPTICAL WAVEGUIDE WITH MULTIPLE CORE LAYERS AND METHOD  
2       OF FABRICATION THEREOF

3

4

5       FIELD OF THE INVENTION

6

7       This invention relates to an optical waveguide with  
8       multiple core layers and a method of fabrication  
9       thereof.

10

11       In particular, the invention relates to a doped planar  
12       waveguide with multiple core layers and which includes  
13       both active and passive components and to a method of  
14       fabricating a planar waveguide for an optical circuit  
15       in which the core is composed of layers of different  
16       materials.

17

18

19       BACKGROUND OF THE INVENTION

20

21       Planar waveguides can be passive devices or can  
22       include active components; for example, modulators,  
23       couplers, and switches. Planar waveguides  
24       incorporating active components are extremely  
25       advantageous as they can be used to provide integrated  
26

27

1       optic packages which can serve as complete transmitting  
2       modules with, for example, components for amplitude or  
3       phase modulation, or multiplexing in an optical  
4       communication network.

5       Rare earth doped fibre amplifiers, for example erbium  
6       or neodymium doped fibre amplifiers, are known to have  
7       several advantages in optical communication networks  
8       such as high gain, low noise, high power conversion  
9       efficiency and wide spectral bandwidth. The present  
10      invention seeks to provide the same advantages in  
11      planar rare earth doped waveguides and moreover to  
12      provide a laser waveguide amplifier which can be used,  
13      for example, in an optical communication network to  
14      amplify attenuated signals.

16      Planar waveguide technology is important in the  
17      fabrication of lasers and optical amplifiers due to the  
18      superior stability, compact geometry of planar  
19      waveguide technology. Also, active components, for  
20      example modulators, can be integrated into the planar  
21      device.

23      A variety of techniques, including flame hydrolysis  
24      deposition (FHD), sputtering, plasma enhanced chemical  
25      vapour deposition (CVD) and ion-exchange can be used in  
26      the fabrication of silica-based planar waveguides doped  
27      with rare-earth ions and which display laser  
28      characteristics.

30      In such laser amplifying waveguides, it is desirable to  
31      obtain a high concentration of rare earth ions in order  
32      to achieve very compact and efficient devices.  
33      However, high concentrations of rare earth ions in a  
34      waveguide layer with relatively low solubility can  
35      result in the formation of clusters of rare earth ions.

1      The interaction between the rare earth ions in such  
2      clusters quenches the excited state required for the  
3      lasing process and thus degrades the optical  
4      amplification provided by the waveguide.  
5

6      Other complications arise in the fabrication of laser  
7      waveguides for applications which require single mode  
8      transmission, narrow spectral bandwidths, and/or  
9      precise control of the lasing wavelength depend  
10     critically on their cavity type. Laser waveguides  
11     which have butt-coupled mirrors on the waveguide ends  
12     or dielectric reflection mirrors are known in the art  
13     but suffer to a greater or lesser degree from certain  
14     disadvantages; for example, low spectral selectivity.  
15

16     Bragg gratings incorporated in a waveguide core can  
17     provide enhanced spectral selectivity. The fabrication  
18     of such gratings is affected by the host glass  
19     composition present in the waveguide core which  
20     determine the UV absorption band of the core material  
21     and thus its photosensitive properties. For example,  
22     if phosphorus is used as a core dopant ion it can  
23     alleviate the formation of rare earth ion clusters but  
24     has the disadvantage that it reduces the amount of  
25     absorption in the UV and thus reduces the  
26     photosensitivity of the core. If germanium is used as  
27     a core dopant ion it can increase the photosensitivity  
28     of the core but has the disadvantage of promoting rare  
29     earth cluster formation.  
30

31     The introduction of a Bragg grating can be effected in  
32     a planar waveguide by a number of known methods which  
33     suffer to a greater or lesser degree from certain  
34     disadvantages. The invention provides an optical  
35     waveguide with multiple core layers which is suitable  
36     for forming a laser waveguide with a high degree of

1       spectral selectivity. The waveguide core combines two  
2       different types of silica based layers and these core  
3       layers obviate or mitigate the aforementioned  
4       disadvantages which arise when seeking to fabricate an  
5       in-core Bragg grating to enhance the spectral  
6       selectivity of the laser waveguide. The waveguide  
7       formed enables in-core Bragg grating formation at a  
8       range of UV wavelengths above 150 nm.

9

10      SUMMARY OF THE INVENTION

11

12      In accordance with a first aspect of the invention  
13       there is provided an optical waveguide with multiple  
14       core layers comprising: a substrate; a waveguide core  
15       formed on said substrate; and an upper cladding layer  
16       embedding said waveguide core; wherein said waveguide  
17       core comprises a first core layer and a second core  
18       layer.

19

20      Preferably, the substrate comprises silicon and/or  
21       silica and/or sapphire.

22

23      Preferably, the substrate includes an intermediate  
24       layer. The intermediate layer may include a buffer  
25       layer formed on the substrate. The buffer layer may  
26       comprise a thermally oxidised layer of the substrate.

27

28      The intermediate layer may further include a lower  
29       cladding layer formed on said buffer layer.

30

31      Preferably, the thickness of the buffer layer is in the  
32       range 5  $\mu\text{m}$  to 20  $\mu\text{m}$ .

33

34      The second core layer may be formed on the first core  
35       layer and said first core layer may be formed on the  
36       substrate. Alternatively, the first core layer may be

1 formed on the second core layer and said second core  
2 layer may be formed on the substrate. A further first  
3 core layer may be formed on the second core layer such  
4 that the first core layer sandwiches the second core  
5 layer.

6

7 Preferably, the first core layer includes a dopant to  
8 permit the first core layer to exhibit a photosensitive  
9 response. The first core layer may include silica.

10

11 Preferably, the first core layer includes a germanium  
12 oxide and/or a boron oxide. The first core layer  
13 dopant may include dopant ions. Preferably, the first  
14 core layer dopant ions include tin and/or cerium and/or  
15 sodium.

16

17 The second core layer may include a dopant to induce  
18 amplification of an optical signal transmitted through  
19 said waveguide core. The second core layer may include  
20 silica. The second core layer may include a phosphorus  
21 oxide. The second core layer dopants may include  
22 dopant ions. The second core layer dopant may include  
23 a mobile dopant.

24

25 Preferably, the second core layer dopants include a  
26 rare earth and/or a heavy metal and/or compounds of  
27 these elements. More preferably, the rare earth is  
28 Erbium or Neodymium.

29

30 Preferably, the refractive indices of the first core  
31 layer and the second core layer are substantially  
32 equal.

33

34 Preferably, the refractive index of the waveguide core  
35 differs from that of the substrate by at least 0.05%.

36

1 Preferably, the thickness of the first core layer is in  
2 the range 0.2  $\mu\text{m}$  to 30  $\mu\text{m}$ .

3

4 Preferably, the thickness of the second core layer is  
5 in the range 0.2  $\mu\text{m}$  to 30  $\mu\text{m}$ .

6

7 Preferably, the width of the waveguide core lies in the  
8 range 0.4  $\mu\text{m}$  to 60  $\mu\text{m}$ .

9

10 The upper cladding layer and the lower cladding layer  
11 may comprise the same material. The refractive index  
12 of the substrate and the refractive index of the upper  
13 cladding layer may be substantially equal.

14

15 In accordance with a second aspect of the invention  
16 there is provided a method of fabricating a waveguide  
17 comprising the steps of: providing a substrate; forming  
18 a waveguide core on the substrate; and forming an upper  
19 cladding layer to embed the waveguide core, wherein  
20 the waveguide core is formed from a first core layer  
21 and a second core layer.

22

23 The formation of the substrate may include the  
24 formation of an intermediate layer formed on said  
25 substrate. The formation of the intermediate layer may  
26 include the formation of a buffer layer. The buffer  
27 layer may be formed by thermally oxidising the  
28 substrate.

29

30 The formation of the intermediate layer may further  
31 include the formation of a lower cladding layer formed  
32 on said buffer layer. The formation of the lower  
33 cladding layer may include doping said lower cladding  
34 layer with a dopant. The dopant may include dopant  
35 ions.

36

1 Preferably, the second core layer is formed on the  
2 first core layer and the first core layer is formed on  
3 the substrate. Alternatively, the first core layer may  
4 be formed on the second core layer and said second core  
5 layer may be formed on the substrate.

6

7 A further first core layer may be formed on the second  
8 core layer such that the first core layer sandwiches  
9 the second core layer.

10

11 The steps of forming any one of the substrate, first  
12 core layer, the second core layer, and the upper  
13 cladding layer may comprise the steps of:

14 depositing each layer; and  
15 at least partially consolidating each layer.

16

17 Preferably, any one of the substrate, the first core  
18 layer, the second core layer and the upper cladding  
19 layer partially consolidated after deposition is fully  
20 consolidated with the full consolidation of any other  
21 of the first core layer, the second core layer or the  
22 upper cladding layer.

23

24 Preferably, the formation of the first core layer  
25 includes the doping of the first core layer with a  
26 dopant.

27

28 Preferably, the first core layer dopant permits the  
29 first core layer to exhibit a photosensitive response.

30

31 Preferably, the formation of the second core layer  
32 includes the doping of the second core layer with a  
33 dopant.

34

35 Preferably, the second core layer dopant induces  
36 amplification of an optical signal transmitted through

1       said waveguide core.

2

3       The formation of the substrate may include the doping  
4       of the substrate with a dopant. The dopant may include  
5       dopant ions.

6

7       Preferably, the substrate dopant includes a mobile  
8       dopant.

9

10      Preferably, said first core layer dopant ions include  
11      tin and/or cerium and/or sodium.

12

13      Preferably, said second core layer dopant ions include  
14      a rare earth and/or a heavy metal and/or compounds  
15      thereof.

16

17      Preferably, said rare earth is Erbium and/or Neodymium.

18

19      Preferably, the concentration of the first core layer  
20      dopant is selectively controlled during the formation  
21      of the first core layer and the concentration of the  
22      second core layer dopant is selectively controlled  
23      during the formation of the second core layer so that  
24      the refractive index of the first core layer and the  
25      refractive index of the second core layer are  
26      substantially equal.

27

28      Preferably, the concentrations of the first core layer  
29      dopant and second core layer dopant are controlled to  
30      give a refractive index for the waveguide core which  
31      differs from that of the substrate layer by at least  
32      0.05%.

33

34      The lower cladding layer and said buffer layer may be  
35      formed substantially in the same step. At least one of  
36      the substrate, the first core layer, the second core

1       layer, and the upper cladding layer may be deposited by  
2       a Flame Hydrolysis Deposition process and/or Chemical  
3       Vapour Deposition process. The Chemical Vapour  
4       Deposition process may be a Low Pressure Chemical  
5       Vapour Deposition process or a Plasma Enhanced Chemical  
6       Vapour Deposition process.

7

8       Preferably, the consolidation is by fusing using a  
9       Flame Hydrolysis Deposition burner. Alternatively, the  
10      consolidation may be by fusing in a furnace.

11

12      The step of fusing the lower cladding layer and the  
13      step of fusing the first core layer and/or the second  
14      core layer may be performed simultaneously. The  
15      waveguide core may be formed from the first core layer  
16      and the second core layer using a dry etching technique  
17      and/or a photolithographic technique and/or a  
18      mechanical sawing process. The dry etching technique  
19      may comprise a reactive ion etching process and/or a  
20      plasma etching process and/or an ion milling process.

21

22      The waveguide core formed from the first core layer and  
23      the second core layer may be square or rectangular in  
24      cross-section.

25

26      In accordance with a third aspect of the invention  
27      there is provided a laser waveguide with multiple core  
28      layers comprising a waveguide according to the first  
29      aspect of the invention, the laser waveguide further  
30      comprising:

31           at least one grating formed in said waveguide  
32      core.

33

34      Preferably, the laser waveguide further comprises at  
35      least one optical interference mirror.

36

1 More preferably, the optical interference mirror is  
2 provided at the input of the waveguide. The  
3 interference mirror may be butt-coupled to or directly  
4 deposited at the input of the waveguide.

5

6 The laser waveguide may include two mirrors and a  
7 grating. Alternatively, the laser waveguide may  
8 include one mirror and two gratings. Alternatively,  
9 the laser waveguide may include three gratings. The  
10 grating formed may be a Bragg grating. The grating may  
11 form an output coupler for said laser waveguide.

12

13 The laser waveguide may further comprise an optical  
14 interference mirror butt coupled to or directly  
15 deposited at the output of the waveguide.

16

17 In accordance with a fourth aspect of the invention  
18 there is provided method of fabricating a laser  
19 waveguide, comprising forming a waveguide according to  
20 the method of the second aspect of the invention, the  
21 method of fabricating the laser waveguide further  
22 including the steps of:

23 forming at least one grating in said waveguide  
24 core.

25

26 The method may further include the step of attaching at  
27 least one optical interference mirror to the waveguide.

28

29 The optical interference mirror may be attached to an  
30 input of the waveguide.

31

32 The grating may be formed using a laser operating at a  
33 wavelength in the range of 150 nm to 400 nm through a  
34 phase mask deposited on top of said upper cladding  
35 layer of the waveguide. The mask may be a quartz mask.  
36 The grating may be formed using an interference

1 side writing technique. The grating may be formed  
2 using a direct writing technique. The grating formed  
3 may be a Bragg grating.

4

5 Preferably, in the above method, the optical  
6 interference mirror is butt-coupled to or directly  
7 deposited at the input of the waveguide.

8

9 The method may further comprise the step of attaching a  
10 second optical interference mirror to the output of the  
11 waveguide.

12

13 DESCRIPTION OF THE DRAWINGS

14

15 Embodiments of the present invention will now be  
16 described, by way of example only, with reference to  
17 the accompanying drawings, in which:-

18

19 Figs. 1A to 1C are schematic cross-sectional diagrams  
20 of a waveguide with multiple core layers during various  
21 stages of fabrication.

22

23 Fig. 2A is a schematic representation of a laser  
24 waveguide formed from the waveguide shown in Figs. 1A  
25 to 1C; and

26

27 Fig. 2B is a detail, to an enlarged scale, of the  
28 structure shown in Fig. 2A.

29

30

31 DETAILED DESCRIPTION OF THE INVENTION

32

33 Referring now to the drawings, Figs. 1A to 1C  
34 illustrate schematically stages in the fabrication of a  
35 waveguide with a multi-layered core according to the  
36 invention.

1 Referring now to Fig. 1A, there is illustrated a  
2 waveguide 1 which is fabricated from a substrate 2.  
3 The substrate 2 comprises a silicon wafer. However,  
4 other suitable substrates including silica and  
5 sapphire, may be used.

6  
7 A silica buffer layer 3, comprising a thermally  
8 oxidised layer of the substrate 2, is formed on the  
9 substrate 2. The thickness of the buffer layer 3 is 15  
10  $\mu\text{m}$  which lies in a preferred range of 5  $\mu\text{m}$  to 20  $\mu\text{m}$ .

11  
12 A suitable method, for example, a flame hydrolysis  
13 deposition (FHD) method, is used to deposit a first  
14 core layer 4 on top of the buffer layer 3. The  
15 thickness of the first core layer 4 is 2  $\mu\text{m}$  which lies  
16 in a preferred range of 0.2  $\mu\text{m}$  to 30  $\mu\text{m}$ .

17  
18 The material included in the first core layer 4  
19 provides a high photosensitive response to an optical  
20 signal. In a preferred embodiment, the first core  
21 layer 4 includes a high concentration of Germanium  
22 dopant, for example 17 %wt, co-doped with Boron, for  
23 example 5 %wt. Other dopant ions can be included, or a  
24 mixture of dopant ions, for example, tin, cerium,  
25 and/or sodium.

26  
27 The dopant and co-dopants are introduced during the  
28 deposition of the first core layer 4. The Germanium  
29 dopant induces a high photo-sensitive response and the  
30 Boron co-dopant lowers the refractive index induced by  
31 the high level of Germanium in the first core layer 4.  
32 The concentrations of the dopant and co-dopant are  
33 adjusted to 17% wt and 5% wt to give a difference  
34 between the refractive index of the first core layer 4  
35 and the refractive index of the buffer layer 3 of 0.75%  
36 which lies in a preferred range of 0.05% to 2.0% .

1 The first core layer 4 is then consolidated by a  
2 suitable method, for example by a second pass of the  
3 FHD burner or by consolidating the waveguide 1 in an  
4 electrical furnace.

5

6 Fig. 1B shows a further stage in the fabrication of the  
7 waveguide 1 in which a second core layer 5 is formed on  
8 the first core layer 4.

9

10 The second core layer 5 is deposited on the first core  
11 layer 4 using a suitable method, for example FHD, and  
12 is then suitably consolidated, for example, in an  
13 electrical furnace.

14

15 The second core layer 5 is doped with rare earth dopant  
16 ions, for example  $Er^{+3}$ , using an aerosol doping  
17 technique, and co-doped, for example, with Phosphorus  
18 during the deposition of the second core layer 5. The  
19 thickness of the second core layer 5 is  $4\mu m$ , which lies  
20 in the range of  $0.2\mu m$  to  $30\mu m$ .

21

22 Alternative methods can be used to dope the second core  
23 layer 5 such as solution doping. Preferably, the dopant  
24 and co-dopant are simultaneously introduced in a  
25 controlled manner during the deposition of the second  
26 core layer 5. The concentrations of the dopant and co-  
27 dopant can be controlled so that the second core layer  
28 5 provides the desired signal gain for optical signals  
29 propagating through the waveguide and also to ensure  
30 that the refractive index of the second core layer 5 is  
31 matched to the refractive index of the first core layer  
32 4. In this embodiment, the indices are substantially  
33 matched. Alternatively, the first core layer 4 and the  
34 second core layer 5 can be subjected to a further  
35 process, for example, UV trimming, to effect matching  
36 of their refractive indices.

1 The photosensitive response of the first core layer 4  
2 in combination with the optical signal gain of the  
3 second core layer 5 effect the overall level of optical  
4 signal amplification provided by the waveguide 1.

5

6 A waveguide core 6 is then formed from the first core  
7 layer 4 and the second core layer 5 by using a suitable  
8 method, for example conventional photolithographic  
9 and/or reactive ion etching (RIE) methods. A portion  
10 of the second core layer 5 is suitably masked and the  
11 unwanted portions of the second core layer 5 and the  
12 underlying first core layer 4 are etched away to leave  
13 the waveguide core 6. The overall dimensions of the  
14 waveguide core 6 formed are  $6\mu\text{m} \times 6\mu\text{m}$  which is in a  
15 preferred range of  $0.4\mu\text{m} \times 0.4\mu\text{m}$  to  $60\mu\text{m} \times 60\mu\text{m}$ .

16

17 The co-dopant, here Boron, in the first core layer 4  
18 reduce the refractive index of the waveguide core 6 and  
19 enable single mode operation even for large waveguide  
20 cores, for example waveguide cores whose dimensions are  
21 in the range of  $0.4\mu\text{m} \times 0.4\mu\text{m}$  to  $60\mu\text{m} \times 60\mu\text{m}$ . The co-  
22 dopant in the first core layer 4 can also provide other  
23 advantages such as enabling higher refractive index  
24 changes to occur during later stages of fabrication of  
25 a waveguide with multiple core layers.

26

27 The first core layer 4 effectively can reduce the  
28 optical signal gain provided by the second core layer  
29 5. It is thus advantageous for the first core layer 4  
30 to be as photosensitive as possible in particular as  
31 the refractive index modulation no longer occurs over  
32 the entire volume of the waveguide core 6.

33

34 Fig. 1C shows a further stage in the fabrication of the  
35 waveguide. An upper cladding layer 7 is deposited on  
36 the waveguide core 6 using an FHD method. The upper

1       cladding layer 7 embeds the waveguide core 6. The  
2       upper cladding layer 7 is doped during deposition, for  
3       example with Phosphorus and Boron, to adjust its  
4       refractive index until the refractive index of the  
5       upper cladding layer 7 matches the refractive index of  
6       the buffer layer 3. The upper cladding layer 7 is then  
7       consolidated, for example in an electrical furnace.  
8

9       In a second preferred embodiment of the invention, a  
10      lower cladding layer is formed on top of the buffer  
11      layer 3 before the first core layer 4 is deposited and  
12      in which the level of dopant in the upper cladding  
13      layer 7 is adjusted until the refractive index of the  
14      upper cladding layer 7 matches that of the lower  
15      cladding layer. The lower cladding layer can be  
16      deposited and consolidated using the same techniques as  
17      the upper cladding layer 7.  
18

19      In an alternative layer structure the first core layer  
20      4 may be deposited on top of the second core layer 5 or  
21      respective first core layers 4 may be provided both  
22      below and on top of the second core layer 5. The core  
23      layer 5 is then sandwiched between two photo-sensitive  
24      first core layers 4 increasing the coupling coefficient  
25      of the device.  
26

27      It is possible also, for certain applications, to dope  
28      the photo-sensitive first core layer 4 with a small  
29      amount of rare earth ions.  
30

31      Referring now to Figs. 2A and 2B of the drawings, there  
32      is shown a schematic diagram of laser waveguide  
33      according to the invention. Figs. 2A and 2B show a  
34      cross-section parallel to the longitudinal axis of the  
35      laser waveguide core, such that the waveguide core is  
36      seen only in profile.

1 Fig. 2A shows a planar laser waveguide 10 incorporating  
2 a Bragg grating 11. The laser waveguide 10 includes a  
3 silicon substrate layer 12 and a silica buffer layer 13  
4 comprising a thermally oxidised layer of the substrate  
5 12. The buffer layer 13 is formed on the substrate  
6 layer 12.

7

8 Fig. 2B is an enlarged view of a section of Fig. 2A. A  
9 first core layer 14 is deposited and consolidated on  
10 the buffer layer 13 and second core layer 15 is  
11 deposited and consolidated on the first core layer 14  
12 using the techniques described above for the deposition  
13 and consolidation of first and second core layers 4 and  
14 5 in the waveguide 1. The first core layer 14 can  
15 alternatively be formed on an lower cladding layer (not  
16 shown) formed on buffer layer 13.

17

18 The second core layer 15 is doped with neodymium  
19 instead of the erbium used as a dopant in the second  
20 core layer 5. Fig. 2A represents a cross-section  
21 through the laser waveguide 10 parallel to the  
22 direction of light propagation through the waveguide 10  
23 (i.e., normal to the cross-sectional plane through the  
24 waveguide shown in Fig. 1C). The waveguide core 16 is  
25 formed from said first core layer 14 and said second  
26 core layer 15 using the same technique described above  
27 for the formation of the first core layer 4 and the  
28 second core layer 15.

29

30 An upper cladding layer 17 is then deposited on the  
31 second core layer 15 and the grating 11. The upper  
32 cladding layer 17 is deposited and consolidated using  
33 the same methods as described above for the deposition  
34 and consolidation of the upper cladding layer 7 in the  
35 fabrication of waveguide 1.

36

1 The laser cavity of the laser waveguide 10 is  
2 fabricated by writing the Bragg grating 11 into a  
3 generally central portion of the first core layer 14  
4 and the second core layer 15. Conventionally, the  
5 Bragg grating 11 may be written using a KrF excimer  
6 laser operating at 248 nm through a quartz phase mask  
7 deposited on top of the upper cladding layer.

8

9

10 An input 18 of the laser waveguide 10 provides an  
11 optical signal at a pump wavelength to the laser  
12 waveguide 10. An optical interference mirror 19 butt-  
13 coupled to the input end 18 of the laser waveguide 10  
14 has a high reflectivity ( $R_{sig} = 99.9\%$ ) around the maxima  
15 of the desired output wavelength and has a high  
16 transmittance at the pump wavelength ( $T_{pump} > 95\%$ ). The  
17 grating 11 forms an output coupler at the output 20 of  
18 the laser waveguide 10.

19

20 The grating 11 is designed for use at 1050 nm and the  
21 reflectivity of the grating 11 formed saturates at 80%.  
22 The phase mask used to form the grating 11 has a pitch  
23 of 720 nm. In other embodiments, however, it is  
24 possible to form gratings 11 which can be used at a  
25 wavelength in the range of 500 nm to 2100 nm by using  
26 suitable phase masks.

27

28 In another embodiment of a laser waveguide, a grating  
29 11 can be provided at both the input 18 and the output  
30 20 of the laser waveguide 10, preferably with both  
31 gratings having substantially the same Bragg wavelength  
32 thus providing a distributed Bragg reflection laser  
33 (DBR).

34

35 In yet another embodiment, a distributed feedback laser  
36 (DFB) can also be formed by having a grating extending

1 along the length of the gain cavity formed by the core  
2 layer 5.

3

4 Further, a multicavity laser can be formed by butt-  
5 coupling another mirror to the output end of the laser  
6 waveguide 10. These external mirrors can be bulk  
7 mirror butt-coupled or mirrors directly deposited on  
8 the ends of the waveguide. A multiple wavelength laser  
9 can be provided by photoimprinting a sampled grating in  
10 the waveguide core, with precise control of channel  
11 spacing. Additionally, a multiple wavelength laser can  
12 be achieved by exposing the same core area to very  
13 similar UV patterns, with each exposure determining  
14 each one of the emission wavelengths of the  
15 superimposed Bragg gratings. An additional grating can  
16 be defined to provide gain equalisation for the several  
17 wavelengths.

18

19 Thus, a multicavity laser can be constructed by using  
20 two mirrors and a grating, one mirror and two gratings,  
21 or indeed three gratings.

22

23 Still further, in a different application, for example,  
24 optical amplifiers, a grating can also be formed on the  
25 first core layer 4 to act as a "tap" to flatten optical  
26 gain spectra.

27

28 While several embodiments of the present invention have  
29 been described and illustrated, it will be apparent to  
30 those skilled in the art once given this disclosure  
31 that various modifications, changes, improvements and  
32 variations may be made without departing from the  
33 spirit or scope of this invention.

## 1      Claims:-

2

3      1. An optical waveguide with multiple core layers  
4      for transmitting an optical signal, the waveguide  
5      including:

6              a substrate;

7              a waveguide core formed on said substrate; and  
8              an upper cladding layer embedding said waveguide  
9      core;

10              wherein said waveguide core comprises a first core  
11      layer and a second core layer.

12

13      2. A waveguide as claimed in any preceding claim,  
14      wherein the substrate comprises silicon and/or silica  
15      and/or sapphire.

16

17      3. A waveguide as claimed in either preceding claim,  
18      wherein the substrate includes an intermediate layer.

19

20      4. A waveguide as claimed in Claim 3, and wherein the  
21      intermediate layer includes a buffer layer formed on  
22      the substrate.

23

24      5. A waveguide as claimed in Claim 4, wherein said  
25      buffer layer comprises a thermally oxidised layer of  
26      the substrate.

27

28      6. A waveguide as claimed in any one of Claims 4 or  
29      5, wherein the intermediate layer further includes a  
30      lower cladding layer formed on said buffer layer.

31

32      7. A waveguide as claimed in any one of Claims 4 to  
33      6, wherein the thickness of the buffer layer is in the  
34      range 5  $\mu\text{m}$  to 20  $\mu\text{m}$ .

35

36

1       8. A waveguide as claimed in any preceding claim,  
2       wherein the second core layer is formed on the first  
3       core layer and said first core layer is formed on the  
4       substrate.

5

6       9. A waveguide as claimed in any one of Claims 1 to  
7       7, wherein the first core layer is formed on the second  
8       core layer and said second core layer is formed on the  
9       substrate.

10

11      10. A waveguide as claimed in Claim 8, wherein a  
12       further first core layer is formed on the second core  
13       layer such that the first core layer sandwiches the  
14       second core layer.

15

16      11. An optical waveguide as claimed in any preceding  
17       claim, wherein the first core layer includes a dopant  
18       to permit the first core layer to exhibit a  
19       photosensitive response.

20

21      12. A waveguide as claimed in any preceding claim,  
22       wherein the first core layer includes silica.

23

24      13. A waveguide as claimed in any preceding claim,  
25       wherein the first core layer includes a germanium oxide  
26       and/or a boron oxide.

27

28      14. A waveguide as claimed in of Claims 11 to 13,  
29       wherein the first core layer dopant includes dopant  
30       ions.

31

32      15. A waveguide as claimed in Claim 14, wherein the  
33       first core layer dopant ions include tin and/or cerium  
34       and/or sodium.

35

36      16. An optical waveguide as claimed in any preceding

1 claim, wherein the second core layer includes a dopant  
2 to induce amplification of an optical signal  
3 transmitted through said waveguide core.  
4

5 17. A waveguide as claimed in any preceding claim,  
6 wherein the second core layer includes silica.  
7

8 18. A waveguide as claimed in any preceding claim,  
9 wherein the second core layer includes a phosphorus  
10 oxide.  
11

12 19. A waveguide as claimed in any of Claims 16 to 18,  
13 wherein the second core layer dopants include dopant  
14 ions.  
15

16 20. A waveguide as claimed in Claim 19, wherein the  
17 second core layer dopant includes a mobile dopant.  
18

19 21. A waveguide as claimed in one of Claims 17 to 20,  
20 wherein the second core layer dopants include a rare  
21 earth and/or a heavy metal and/or compounds of these  
22 elements.  
23

24 22. A waveguide as claimed in Claim 21, wherein the  
25 rare earth is Erbium or Neodymium.  
26

27 23. A waveguide as claimed in any preceding claim,  
28 wherein the refractive indices of the first core layer  
29 and the second core layer are substantially equal.  
30

31 24. A waveguide as claimed in any preceding claim,  
32 wherein the refractive index of the waveguide core  
33 differs from that of the substrate by at least 0.05%.  
34

35 25. A waveguide as claimed in any preceding claim,  
36 wherein the thickness of the first core layer is in the

1       range 0.2  $\mu\text{m}$  to 30  $\mu\text{m}$ .

2

3       26. A waveguide as claimed in any preceding claim,  
4       wherein the thickness of the second core layer is in  
5       the range 0.2  $\mu\text{m}$  to 30  $\mu\text{m}$ .

6

7       27. A waveguide as claimed in Claim 25, wherein the  
8       width of the waveguide core lies in the range 0.4  $\mu\text{m}$  to  
9       60  $\mu\text{m}$ .

10

11       28. A waveguide as claimed in any one of Claims 6 to  
12       27, wherein the upper cladding layer and the lower  
13       cladding layer comprise the same material.

14

15       29. A waveguide as claimed in any preceding claim,  
16       wherein the refractive index of the substrate and the  
17       refractive index of the upper cladding layer are  
18       substantially equal.

19

20       30. A method of fabricating a waveguide comprising the  
21       steps of:

22               providing a substrate;

23               forming a waveguide core on the substrate; and

24               forming an upper cladding layer to embed the  
25       waveguide core, wherein the waveguide core is formed  
26       from a first core layer and a second core layer.

27

28       31. A method as claimed in Claim 30, wherein the  
29       formation of the substrate includes the formation of an  
30       intermediate layer formed on said substrate.

31

32       32. A method as claimed in Claim 31, wherein the  
33       formation of the intermediate layer includes the  
34       formation of a buffer layer.

35

36       33. A method as claimed in Claim 33, wherein the

1       buffer layer is formed by thermally oxidising the  
2       substrate.

3

4       34. A method as claimed in any of Claims 32 to 33,  
5       wherein the formation of the intermediate layer further  
6       includes the formation of a lower cladding layer formed  
7       on said buffer layer.

8

9       35. A method as claimed in Claim 34, wherein the  
10      formation of the lower cladding layer includes doping  
11      said lower cladding layer with a dopant.

12

13      36. A method as claimed in Claim 34, wherein the  
14      dopant includes dopant ions.

15

16      37. A method as claimed in any of Claims 30 to 36,  
17      wherein the second core layer is formed on the first  
18      core layer and wherein the first core layer is formed  
19      on the substrate.

20

21      38. A waveguide as claimed in any of Claims 30 to 37,  
22      wherein the first core layer is formed on the second  
23      core layer and said second core layer is formed on the  
24      substrate.

25

26      39. A waveguide as claimed in Claim 37, wherein a  
27      further first core layer is formed on the second core  
28      layer such that the first core layer sandwiches the  
29      second core layer.

30

31      40. A method as claimed in any of Claims 30 to 39,  
32      wherein the steps of forming any one of the substrate,  
33      first core layer, the second core layer, and the upper  
34      cladding layer comprise the steps of:

35            depositing each layer; and

36            at least partially consolidating each layer.

1       41. A method as claimed in Claim 40, wherein any one  
2       of the substrate, the first core layer, the second core  
3       layer and the upper cladding layer partially  
4       consolidated after deposition is fully consolidated  
5       with the full consolidation of any other of the first  
6       core layer, the second core layer or the upper cladding  
7       layer.

8

9       42. A method as claimed in any of Claims 30 to 41,  
10      wherein the formation of the first core layer includes  
11      the doping of the first core layer with a dopant.

12

13      43. A method as claimed in Claim 42, wherein the first  
14      core layer dopant permits the first core layer to  
15      exhibit a photosensitive response.

16

17      44. A method as claimed in any of Claims 30 to 43,  
18      wherein the formation of the second core layer includes  
19      the doping of the second core layer with a dopant.

20

21      45. A method as claimed in any of Claims 30 to 44,  
22      wherein the second core layer dopant induces  
23      amplification of an optical signal transmitted through  
24      said waveguide core.

25

26      46. A method as claimed in any of Claims 30 to 45,  
27      wherein the formation of the substrate includes the  
28      doping of the substrate with a dopant.

29

30      47. A method as claimed in any one of Claims 42 to 46,  
31      wherein the dopant includes dopant ions.

32

33      48. A method as claimed in Claim 47, wherein the  
34      substrate dopant includes a mobile dopant.

35

36      49. A method as claimed in any of Claims 47 to 48,

1 wherein said first core layer dopant ions include tin  
2 and/or cerium and/or sodium.

3

4 50. A method as claimed in any of Claims 47 to 49,  
5 wherein said second core layer dopant ions include a  
6 rare earth and/or a heavy metal and/or compounds  
7 thereof.

8

9 51. A method as claimed in Claim 50, wherein said rare  
10 earth is Erbium and/or Neodymium.

11

12 52. A method as claimed in any of Claims 42 to 51,  
13 wherein the concentration of the first core layer  
14 dopant is selectively controlled during the formation  
15 of the first core layer and the concentration of the  
16 second core layer dopant is selectively controlled  
17 during the formation of the second core layer so that  
18 the refractive index of the first core layer and the  
19 refractive index of the second core layer are  
20 substantially equal.

21

22 53. A method as claimed in Claim 52, wherein the  
23 concentrations of the first core layer dopant and  
24 second core layer dopant are controlled to give a  
25 refractive index for the waveguide core which differs  
26 from that of the substrate layer by at least 0.05%.

27

28 54. A method as claimed in any of Claim 34, wherein  
29 said lower cladding layer and said buffer layer are  
30 formed substantially in the same step.

31

32 55. A method as claimed in any of Claims 40 to 54,  
33 wherein at least one of the substrate, the first core  
34 layer, the second core layer, and the upper cladding  
35 layer is deposited by a Flame Hydrolysis Deposition  
36 process and/or Chemical Vapour Deposition process.

1       56. A method as claimed in Claim 55, wherein the  
2       Chemical Vapour Deposition process is a Low Pressure  
3       Chemical Vapour Deposition process or a Plasma Enhanced  
4       Chemical Vapour Deposition process.

5

6       57. A method as claimed in any of Claims 40 to 56,  
7       wherein the consolidation is by fusing using a Flame  
8       Hydrolysis Deposition burner.

9

10      58. A method as claimed in any of Claims 40 to 57,  
11      wherein the consolidation is by fusing in a furnace.

12

13      59. A method as claimed in either of Claims 57 or 58,  
14      wherein the step of fusing the lower cladding layer and  
15      the step of fusing the first core layer and/or the  
16      second core layer are performed simultaneously.

17

18      60. A method as claimed in any of Claims 30 to 59,  
19      wherein the waveguide core is formed from the first  
20      core layer and the second core layer using a dry  
21      etching technique and/or a photolithographic technique  
22      and/or a mechanical sawing process.

23

24      61. A method as claimed in Claim 60, wherein the dry  
25      etching technique comprises a reactive ion etching  
26      process and/or a plasma etching process and/or an ion  
27      milling process.

28

29      62. A method as claimed in any of Claims 30 to 61,  
30      wherein the waveguide core formed from the first core  
31      layer and the second core layer is square or  
32      rectangular in cross-section.

33

34      63. A laser waveguide with multiple core layers for  
35      transmitting an optical signal, the laser waveguide  
36      comprising a waveguide as claimed in any one of claims

1        1 to 29, the laser waveguide further comprising:  
2                at least one grating formed in said waveguide  
3                core.

4

5        64. A laser waveguide as claimed in Claim 63, wherein  
6                the laser waveguide further comprises at least one  
7                optical interference mirror.

8

9        65. A laser waveguide as claimed in Claim 64, wherein  
10               the optical interference mirror is provided at the  
11               input of the waveguide.

12

13        66. A laser waveguide as claimed in Claim 65, wherein  
14               the interference mirror is butt-coupled to or directly  
15               deposited at the input of the waveguide.

16

17        67. A laser waveguide as claimed in any of Claims 63  
18               to 66, wherein the laser waveguide includes two mirrors  
19               and a grating.

20

21        68. A laser waveguide as claimed in any of Claims 63  
22               to 66, wherein the laser waveguide includes one mirror  
23               and two gratings.

24

25        69. A laser waveguide as claimed in Claim 63, wherein  
26               the laser waveguide includes three gratings.

27

28        70. A laser waveguide as claimed in any of Claims 63  
29               to 69, wherein the grating formed is a Bragg-grating.

30

31        71. A laser waveguide as claimed in any one of Claims  
32               63 to 70, wherein said grating forms an output coupler  
33               for said laser waveguide.

34

35        72. A laser waveguide as claimed in any one of Claims  
36               63 to 71 further comprising an optical interference

1       mirror butt coupled to or directly deposited at the  
2       output of the waveguide.

3

4       73. A method of fabricating a laser waveguide,  
5       comprising forming a waveguide according to a method as  
6       claimed in any of claims 30 to 62, the method of  
7       fabricating the laser waveguide further including the  
8       steps of:

9               forming at least one grating in said waveguide  
10          core.

11

12       74. A method as claimed in Claim 73, further including  
13       the step of attaching at least one optical interference  
14       mirror to the waveguide.

15

16       75. A method as claimed in Claim 74, wherein the  
17       optical interference mirror is attached to an input of  
18       the waveguide.

19

20       76. A method as claimed in Claims 73 to 75, wherein  
21       the grating is formed using a laser operating at a  
22       wavelength in the range of 150 nm to 400 nm through a  
23       phase mask deposited on top of said upper cladding  
24       layer of the waveguide.

25

26       77. A method as claimed in Claim 76, wherein said mask  
27       is a quartz mask.

28

29       78. A method as claimed in Claim 73 to 75, wherein the  
30       grating is formed using a using an interference side  
31       writing technique.

32

33       79. A method as claimed in any one of Claims 73 to 75,  
34       wherein the grating is formed using a direct writing  
35       technique.

36

1       80. A method as claimed in any one of Claims 73 to 79,  
2       wherein the grating formed is a Bragg grating.  
3

4       81. A method as claimed in any one of Claims 74 to 80,  
5       wherein the optical interference mirror is butt-coupled  
6       to or directly deposited at the input of the waveguide.  
7

8       82. A method as claimed in any one of Claims 73 to 80,  
9       further comprising the step of attaching a second  
10      optical interference mirror to the output of the  
11      waveguide.  
12

13      83. A waveguide substantially as described herein and  
14      with reference to Figs. 1A to 1C of the accompanying  
15      drawings.  
16

17      84. A laser waveguide substantially as described  
18      herein and with reference to Figs. 2A and 2B of the  
19      accompanying drawings.  
20

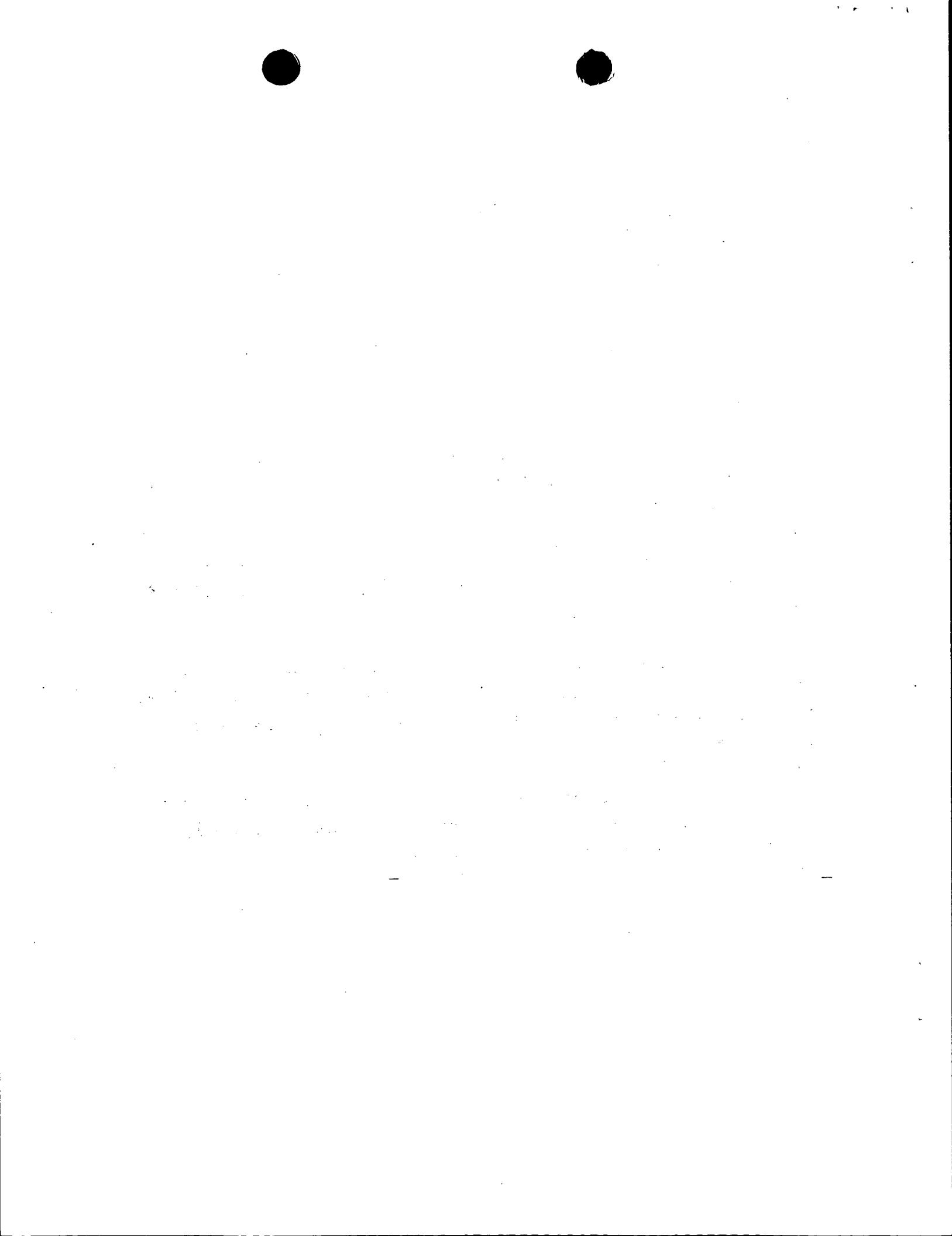
21      85. A method of fabricating a waveguide with multiple  
22      core layers substantially as described herein and with  
23      reference to Figs. 1A to 1C of the accompanying  
24      drawings.  
25

26      86. A method of fabricating a laser waveguide with  
27      multiple core layers substantially as described herein  
28      and with reference to Figs. 2A and 2B of the  
29      accompanying drawings.  
30

31

32

33



1 / 2

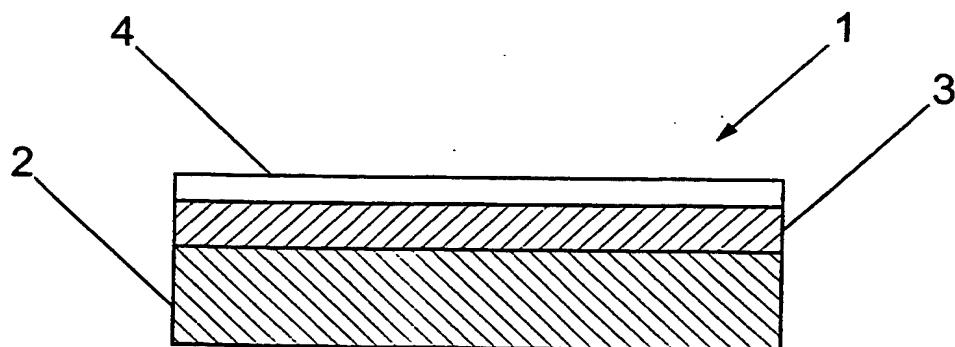


Fig. 1A

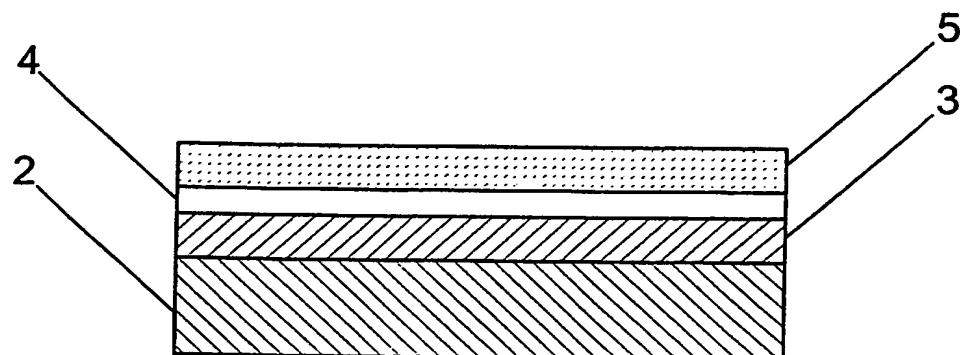


Fig. 1B

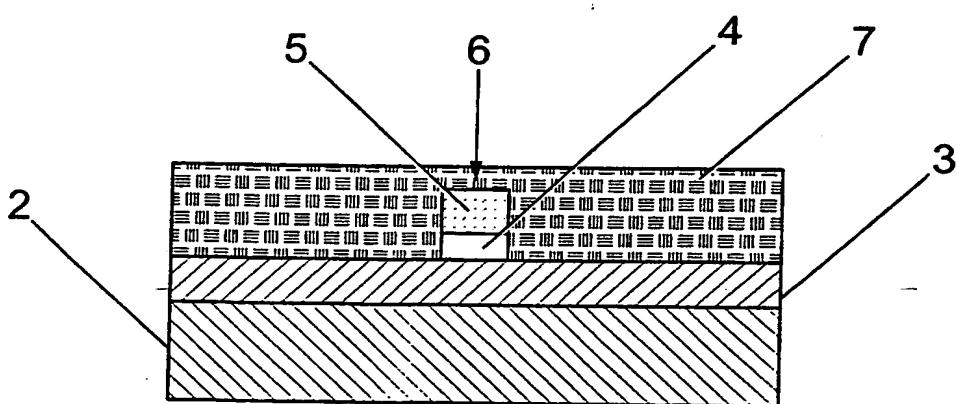
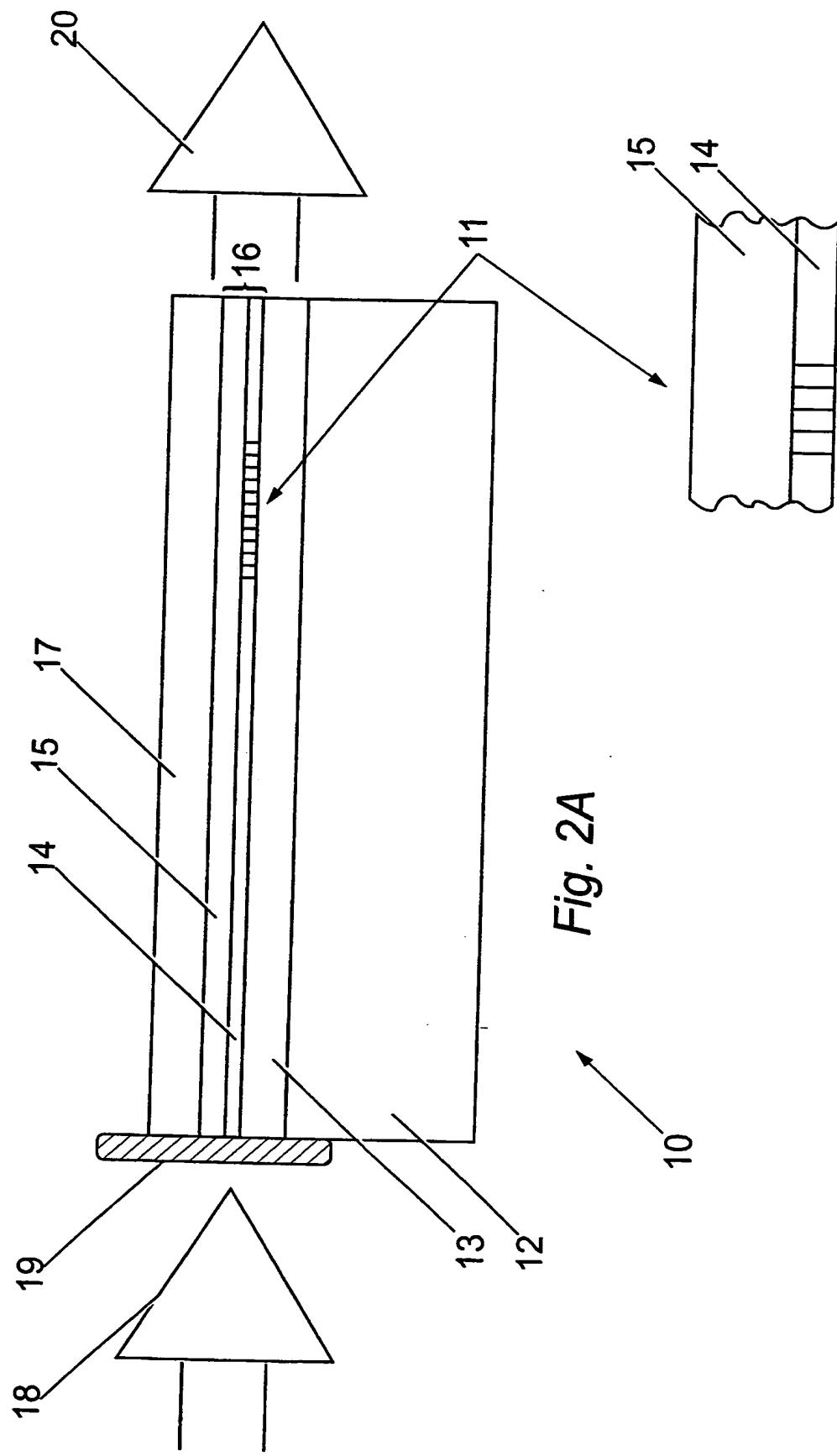


Fig. 1C

JC17 Rec'd PCT/PTO 03 AUG 2001

2 / 2



JC17 Rec'd PCT/PTO 03 AUG 2001

## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/00/00323A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 G02B6/132 H01S3/063

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 G02B H01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 206 925 A (KAMOSHIDA TOSHIKAZU ET AL) 27 April 1993 (1993-04-27) abstract; figures 1,3,4A-4D,8 column 1, line 51 -column 2, line 10 column 3, line 1 - line 19 column 3, line 38 - line 43 column 6, line 52 -column 7, line 21 column 8, line 7 - line 58 column 8, line 60 -column 9, line 25 column 10, line 10 - line 40 column 11, line 24 - line 29 ---	1-61, 82-85
X	US 5 303 319 A (FORD CAROL M ET AL) 12 April 1994 (1994-04-12) abstract; figures 3,4 column 2, line 10 - line 38 column 3, line 29 -column 4, line 43 ---	1,30, 82-85 -/-

 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

## \* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- \*&\* document member of the same patent family

Date of the actual completion of the international search

10 May 2000

Date of mailing of the international search report

20.07.00

Name and mailing address of the ISA

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Authorized officer

Jakober, F

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 00/00323

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 890 850 A (LUCENT TECHNOLOGIES INC) 13 January 1999 (1999-01-13) abstract; figure 9 column 7, line 18 - line 41 ---	1,30, 82-85
A	EP 0 867 985 A (TNO) 30 September 1998 (1998-09-30) abstract page 3, line 20 - line 24 page 4, line 54 -page 5, line 27 page 5; table 1 -----	1-61

# INTERNATIONAL SEARCH REPORT

Intern. application No.  
/GB 00/00323

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
  
3.  Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

**see additional sheet(s)**

1.  As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
  
2.  As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
  
3.  As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
  
  
4.  No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-61,82-85

### Remark on Protest

The additional search fees were accompanied by the applicant's protest.

No protest accompanied the payment of additional search fees.

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

**1. Claims: 1-61,82-85**

An optical waveguide comprising a buffer layer including a thermally oxidised layer.

**2. Claims: 62-81**

A laser waveguide comprising a grating formed in the waveguide core.

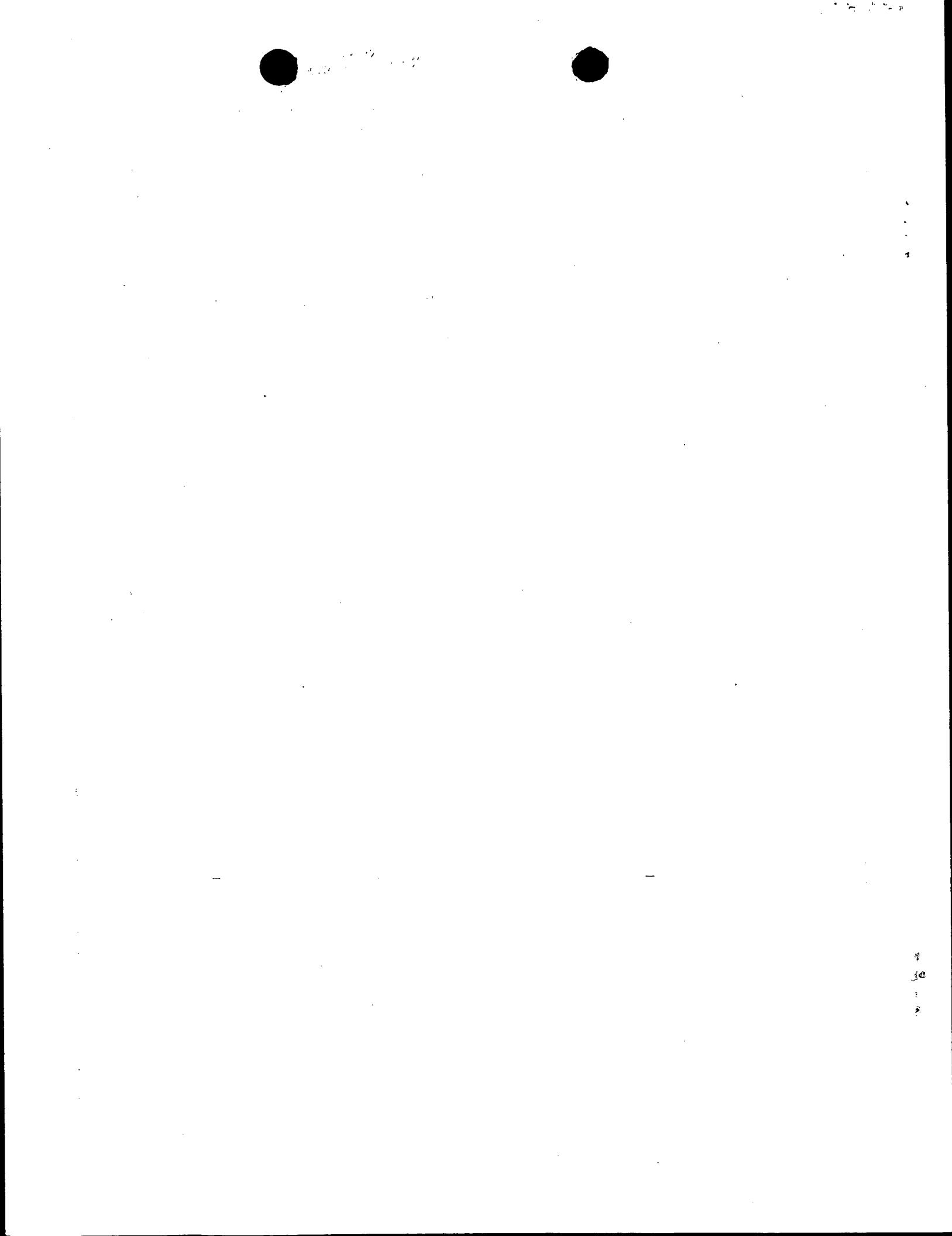
**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International Application No

PCT/00/00323

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US 5206925	A 27-04-1993	JP 2755471 B JP 4060618 A CA 2040527 A,C DE 4120054 A GB 2245984 A,B		20-05-1998 26-02-1992 30-12-1991 02-01-1992 15-01-1992
US 5303319	A 12-04-1994	NONE		
EP 0890850	A 13-01-1999	US 6003222 A JP 11084156 A		21-12-1999 26-03-1999
EP 0867985	A 30-09-1998	JP 11038242 A US 5982973 A		12-02-1999 09-11-1999



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## PATENT COOPERATION TREATY

PCT

REC'D 29 MAY 2001

WIPO

PCT

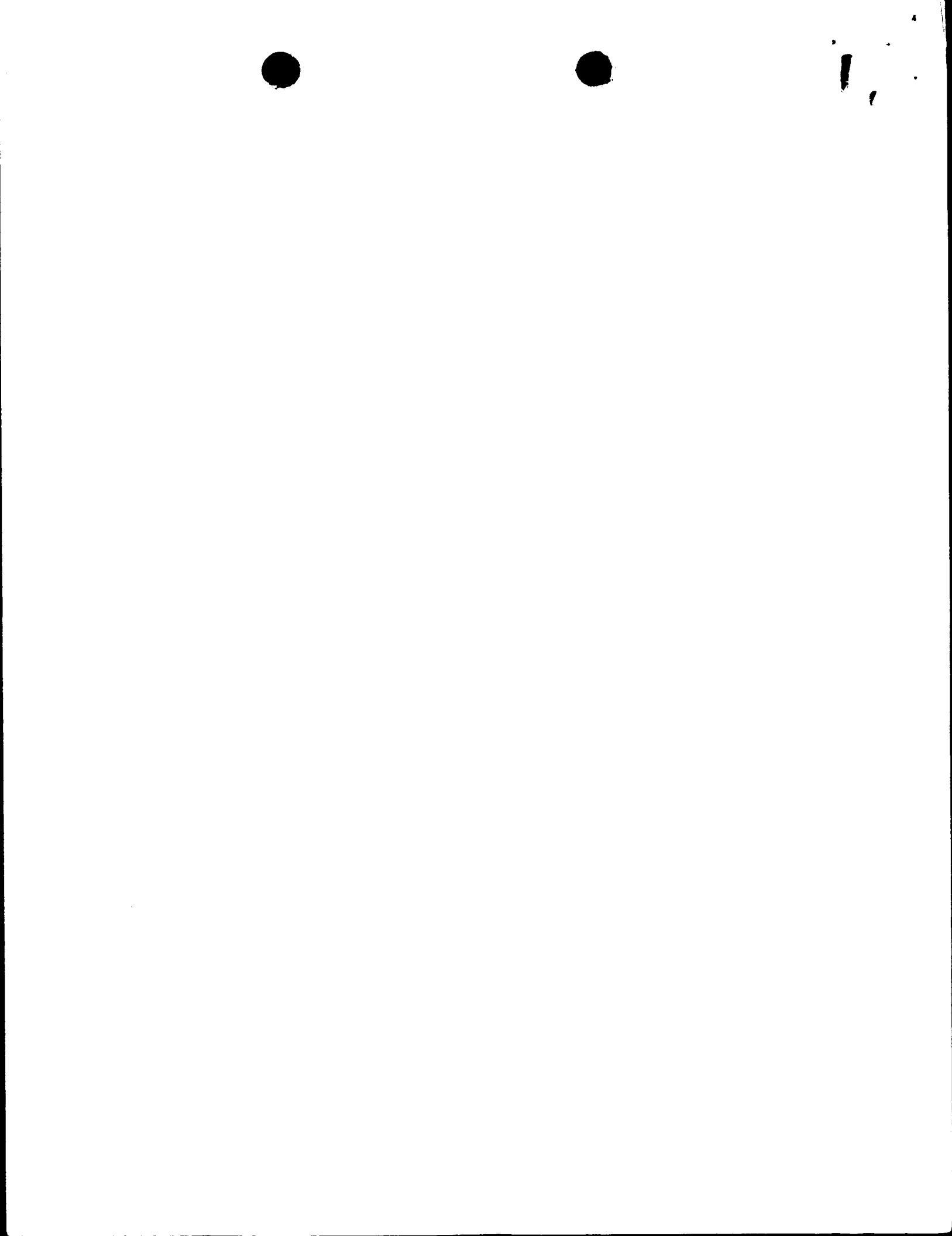
## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference  P23140A/RWA/JMK/PPP	<b>FOR FURTHER ACTION</b>		See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No.  PCT/GB00/00323	International filing date (day/month/year)  07/02/2000	Priority date (day/month/year)  05/02/1999	
International Patent Classification (IPC) or national classification and IPC G02B6/132			
<p><b>Applicant</b> THE UNIVERSITY COURT OF THE UNIVERSITY OF et al.</p>			
<p>1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.</p> <p>2. This REPORT consists of a total of 6 sheets, including this cover sheet.</p> <p><input checked="" type="checkbox"/> This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).</p> <p>These annexes consist of a total of 12 sheets.</p>			
<p>3. This report contains indications relating to the following items:</p> <ul style="list-style-type: none"> <li>I <input checked="" type="checkbox"/> Basis of the report</li> <li>II <input type="checkbox"/> Priority</li> <li>III <input checked="" type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</li> <li>IV <input type="checkbox"/> Lack of unity of invention</li> <li>V <input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement</li> <li>VI <input type="checkbox"/> Certain documents cited</li> <li>VII <input checked="" type="checkbox"/> Certain defects in the international application</li> <li>VIII <input checked="" type="checkbox"/> Certain observations on the international application</li> </ul>			

Date of submission of the demand  04/09/2000	Date of completion of this report  25.05.2001
Name and mailing address of the international preliminary examining authority:   European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340- 3016	Authorized officer  Jakober, F  Telephone No. +31 70 340 3652





INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT

International application No. PCT/GB00/00323

I. Basis of the report

1. With regard to the **elements** of the international application (*Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17)*):

**Description, pages:**

1-18 as originally filed

**Claims, No.:**

1-85 with telefax of 08.03.2001

**Drawings, sheets:**

1/2,2/2 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- the language of publication of the international application (under Rule 48.3(b)).
- the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- contained in the international application in written form.
- filed together with the international application in computer readable form.
- furnished subsequently to this Authority in written form.
- furnished subsequently to this Authority in computer readable form.
- The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- the description, pages:
- the claims, Nos.:



**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT**

International application No. PCT/GB00/00323

the drawings, sheets:

5.  This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):  
*(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)*

6. Additional observations, if necessary:

**III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability**

1. The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

the entire international application.

claims Nos. 62-81.

because:

the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (*specify*):

the description, claims or drawings (*indicate particular elements below*) or said claims Nos. are so unclear that no meaningful opinion could be formed (*specify*):

the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

no international search report has been established for the said claims Nos. 62-81.

2. A meaningful international preliminary examination cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

the written form has not been furnished or does not comply with the standard.

the computer readable form has not been furnished or does not comply with the standard.

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N) Yes: Claims 2-29,31-61



**INTERNATIONAL PRELIMINARY  
EXAMINATION REPORT**

International application No. PCT/GB00/00323

	No:	Claims	1,30
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-61
Industrial applicability (IA)	Yes:	Claims	1-61
	No:	Claims	

**2. Citations and explanations**  
**see separate sheet**

**VII. Certain defects in the international application**

The following defects in the form or contents of the international application have been noted:  
**see separate sheet**

**VIII. Certain observations on the international application**

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:  
**see separate sheet**



**Re Item V**

Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

- D1: US-A-5206925
- D2: US-A-5303319
- D3: EP-A-0890850
- D4: EP-A-0867985

1. None of the independent claims define novel subject-matter. Hence, the application cannot be considered to satisfy the criteria set forth in Art. 33 PCT.

2. Claim 1:

Document D1 discloses in figure 4(d) and the corresponding description an optical waveguide with multiple core layers including

- a substrate (1),
- a waveguide core (3),
- an upper cladding layer embedding said waveguide core (9),
- wherein said waveguide core comprises a first core layer (7 or 8) including a dopant (Ge) permitting the core layer to exhibit a photosensitive response (it is well known that Ge is a photosensitive material) and a second core layer (4) including a dopant to induce amplification (rare earth).

Thus, the claimed waveguide is not novel within the meaning of Art. 33 PCT, since for each feature of claim 1 a counterpart can be found in document D1.

3. Claim 30:

Document D1 discloses in figures 4(a) to 4(d) and the corresponding description a method of fabricating a waveguide comprising the steps of:

- providing a substrate (1),
- forming a waveguide core (3),
- forming an upper cladding layer to embed said waveguide core (9),
- wherein said waveguide core is formed from a first core layer (7 or 8) including a



dopant (Ge) permitting the core layer to exhibit a photosensitive response (it is well known that Ge is a photosensitive material) and a second core layer (4) including a dopant to induce amplification (rare earth).

In view of the above, claim 30 cannot be considered to define novel subject-matter, since for each feature of claim 30 a counterpart can be found in document D1.

4. The dependent claims do not define subject matter which is inventive, since their structural features are either known from D1 or obvious modifications (see passages cited in the international search report).

**Re Item VII**

Certain defects in the international application

1. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the document D1 is not mentioned in the description, nor is this document identified therein.

**Re Item VIII**

Certain observations on the international application

1. Claims 82 to 85 only contain references to the description and the drawings. They are therefore not clear in the meaning of Art. 6 PCT. According to Rule 6.2(a) PCT, claims should not contain such references except where absolutely necessary, which is not the case here. They should therefore have been deleted.
2. The "spirit clause" (page 18, last paragraph) should have been deleted as its presence in the description serves only to cast unnecessary doubt upon the intended scope of the claims.



## 1   Claims

2

3   1. An optical waveguide with multiple core layers for  
4   transmitting an optical signal, the waveguide  
5   including:  
6   a substrate;  
7   a waveguide core formed on the substrate and comprising  
8   a first core layer and a second core layer;  
9   an upper cladding layer embedding said waveguide core;  
10   wherein the first core layer includes a dopant to  
11   permit the first core layer to exhibit a photosensitive  
12   response, and the second core layer includes a dopant  
13   to induce amplification of an optical signal  
14   transmitted through said waveguide core.

15

16   2. An optical waveguide according to Claim 1, wherein the  
17   first core layer includes a germanium oxide to permit  
18   the first core layer to exhibit a photosensitive  
19   response.

20

21   3. An optical waveguide according to Claim 2, wherein the  
22   first core layer further includes a boron oxide.

23

24   4. A waveguide as claimed in any preceding claim, wherein  
25   the substrate comprises silicon and/or silica and/or  
26   sapphire.

27

28   5. A waveguide as claimed in any preceding claim, wherein  
29   the substrate includes an intermediate layer.

30



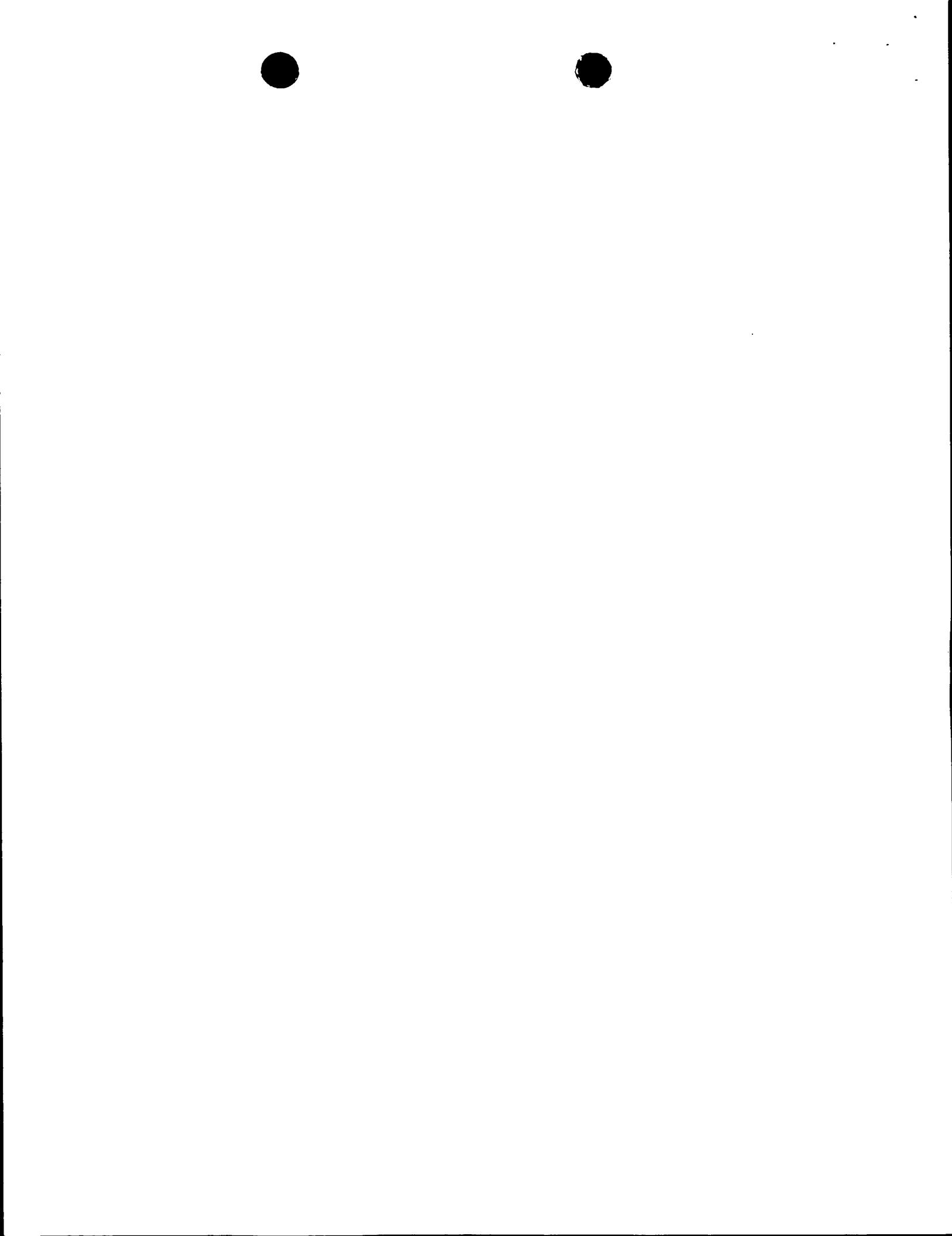
- 1 6. A waveguide as claimed in Claim 5, wherein the  
2 intermediate layer includes a buffer layer formed on  
3 the substrate.
- 4
- 5 7. A waveguide as claimed in Claim 6, wherein said buffer  
6 layer comprises a thermally oxidised layer of the  
7 substrate.
- 8
- 9 8. A waveguide as claimed in Claim 6 or Claim 7, wherein  
10 the intermediate layer further includes a lower  
11 cladding layer formed on said buffer layer.
- 12
- 13 9. A waveguide as claimed in any of Claims 6 to 8, wherein  
14 the thickness of the buffer layer is in the range 5 m  
15 to 20 m.
- 16
- 17 10. A waveguide as claimed in any preceding claim, wherein  
18 the second core layer is formed on the first core layer  
19 and said first core layer is formed on the substrate.
- 20
- 21 11. A waveguide as claimed in any of Claims 1 to 9, wherein  
22 the first core layer is formed on the second core layer  
23 and said second core layer is formed on the substrate.
- 24
- 25 12. A waveguide as claimed in Claim 10, wherein a further  
26 first core layer is formed on the second core layer  
27 such that the first core layer sandwiches the second  
28 core layer.
- 29
- 30 13. A waveguide as claimed in any preceding claim, wherein  
31 the first core layer includes silica.
- 32



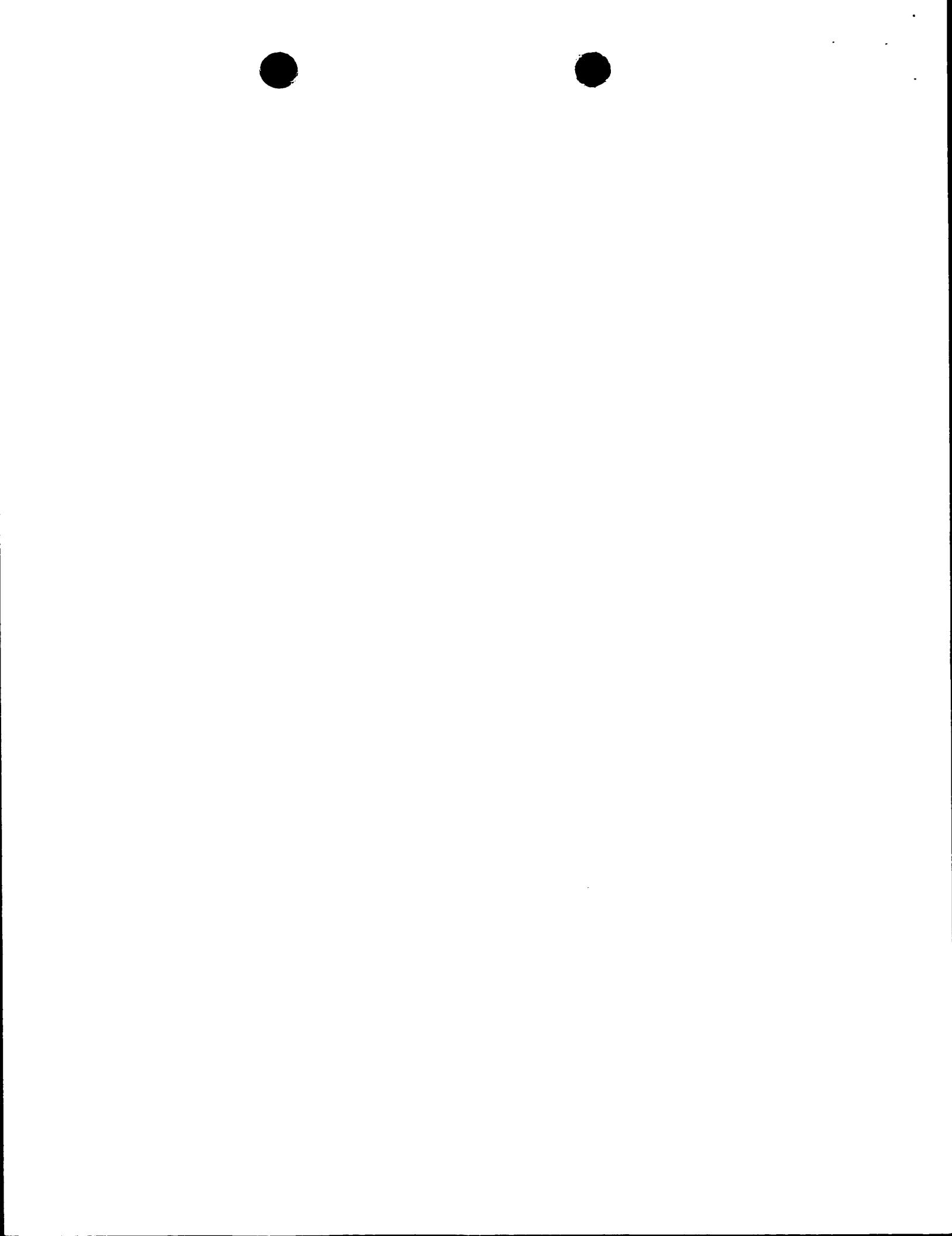
- 1 14. A waveguide as claimed in any preceding claim, wherein  
2 the first core layer dopant includes dopant ions.  
3
- 4 15. A waveguide as claimed in Claim 14, wherein the first  
5 core layer dopant ions include tin and/or cerium and/or  
6 sodium.  
7
- 8 16. A waveguide as claimed in any preceding claim, wherein  
9 the second core layer includes silica.  
10
- 11 17. A waveguide as claimed in any preceding claim, wherein  
12 the second core layer includes a phosphorus oxide.  
13
- 14 18. A waveguide as claimed in any preceding claim, wherein  
15 the second core layer dopant includes dopant ions.  
16
- 17 19. A waveguide as claimed in Claim 18, wherein the second  
18 core layer dopant includes a mobile dopant.  
19
- 20 20. A waveguide as claimed in any of Claims 16 to 19,  
21 wherein the second core layer dopant includes a rare  
22 earth and/or a heavy metal and/or compounds of these  
23 elements.  
24
- 25 21. A waveguide as claimed in Claim 20, wherein the rare  
26 earth is Erbium or Neodymium.  
27
- 28 22. A waveguide as claimed in any preceding claim, wherein  
29 the refractive indices of the first core layer and the  
30 second core layer are substantially equal.  
31



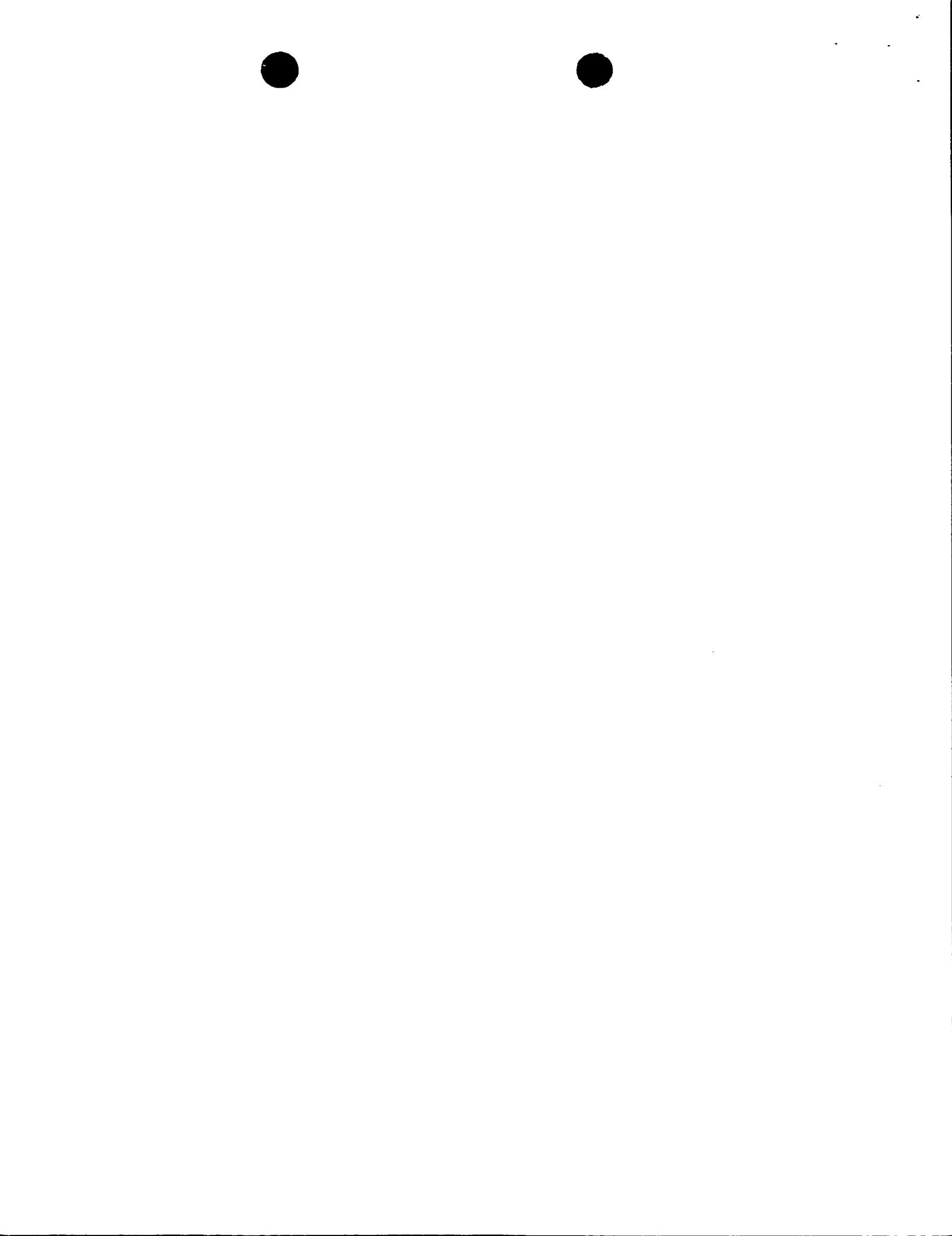
- 1 23. A waveguide as claimed in any preceding claim, wherein
- 2 the refractive index of the waveguide core differs from
- 3 that of the substrate by at least 0.05%.
- 4
- 5 24. A waveguide as claimed in any preceding claim, wherein
- 6 the thickness of the first core layer is in the range
- 7 0.2 m to 30 m.
- 8
- 9 25. A waveguide as claimed in any preceding claim, wherein
- 10 the thickness of the second core layer is in the range
- 11 0.2 m to 30 m.
- 12
- 13 26. A waveguide as claimed in Claim 24, wherein the width
- 14 of the waveguide core lies in the range 0.4 m to 60
- 15 m.
- 16
- 17 27. A waveguide as claimed in any of Claims 8 to 26,
- 18 wherein the upper cladding layer and the lower cladding
- 19 layer comprise the same material.
- 20
- 21 28. A waveguide as claimed in any preceding claim, wherein
- 22 the refractive index of the substrate and the
- 23 refractive index of the upper cladding layer are
- 24 substantially equal.
- 25
- 26 29. An optical waveguide according to any of Claims 1 to
- 27 28, wherein the first core layer includes at least 17%
- 28 wt germanium dopant.
- 29
- 30 30. A method of fabricating a waveguide comprising the
- 31 steps of:
- 32 providing a substrate;



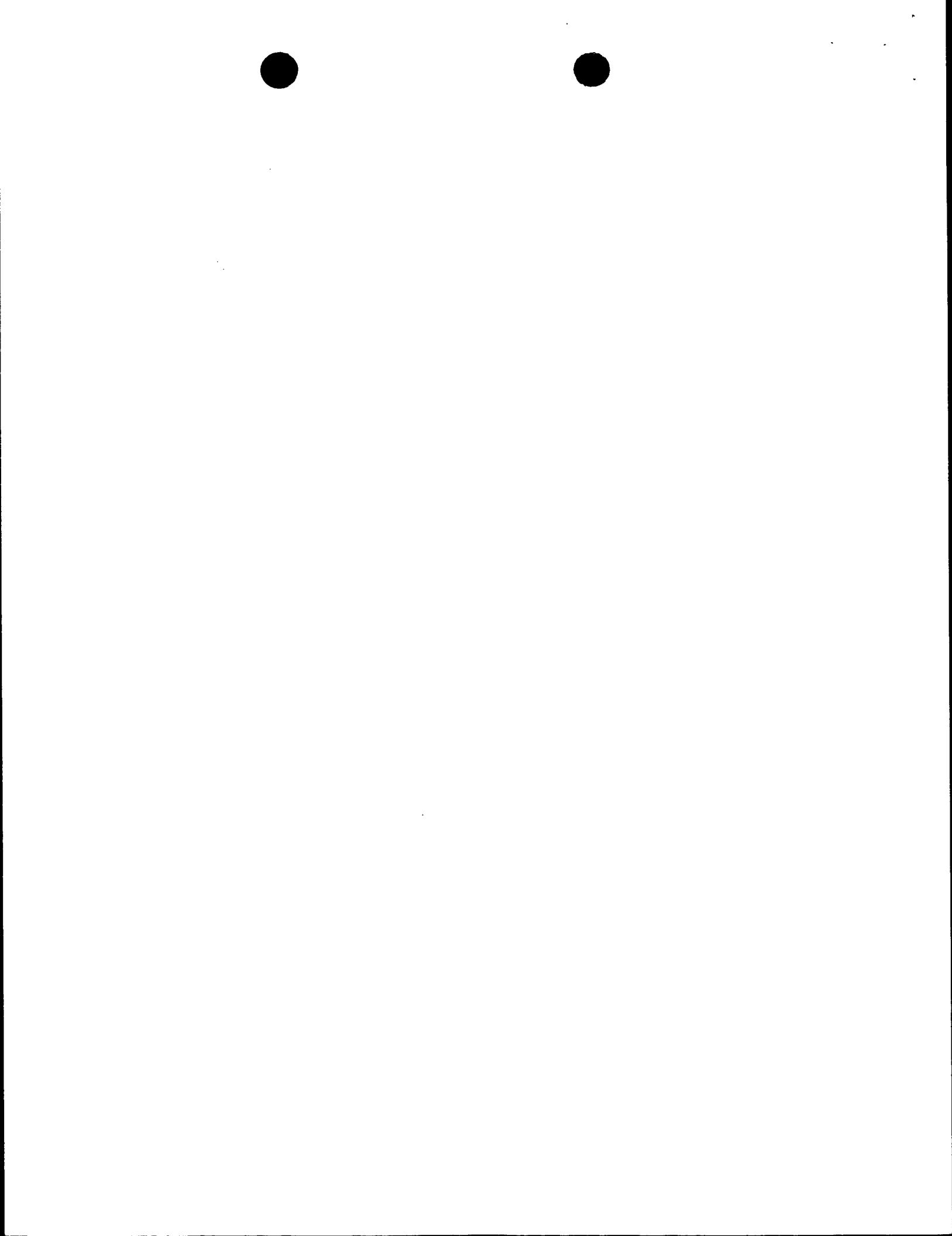
- 1 forming a waveguide core on the substrate, the
- 2 waveguide core comprising a first core layer and a
- 3 second core layer;
- 4 forming an upper cladding layer to embed the waveguide
- 5 core;
- 6 wherein the formation of the first core layer includes
- 7 the doping of the first core layer with a dopant for
- 8 permitting the first core layer to exhibit a
- 9 photosensitive response, and the formation of the
- 10 second core layer includes the doping of the second
- 11 core layer with a dopant for inducing amplification of
- 12 an optical signal transmitted through said waveguide
- 13 core.
- 14
- 15 31. A method according to Claim 30, wherein the dopant used
- 16 to permit the first core layer to exhibit a
- 17 photosensitive response is a germanium dopant.
- 18
- 19 32. A method according to Claim 31, wherein the first core
- 20 layer is co-doped with a boron dopant.
- 21
- 22 33. A method as claimed in any of Claims 30 to 32, wherein
- 23 the formation of the substrate includes the formation
- 24 of an intermediate layer formed on said substrate.
- 25
- 26 34. A method as claimed in Claim 33, wherein the formation
- 27 of the intermediate layer includes the formation of a
- 28 buffer layer.
- 29
- 30 35. A method as claimed in Claim 34, wherein the buffer
- 31 layer is formed by thermally oxidising the substrate.
- 32



- 1 36. A method as claimed in Claim 34 or Claim 35, wherein
- 2 the formation of the intermediate layer further
- 3 includes the formation of a lower cladding layer formed
- 4 on said buffer layer.
- 5
- 6 37. A method as claimed in Claim 36, wherein the formation
- 7 of the lower cladding layer includes doping said lower
- 8 cladding layer with a dopant.
- 9
- 10 38. A method as claimed in Claim 37, wherein the dopant
- 11 includes dopant ions.
- 12
- 13 39. A method as claimed in any of Claims 30 to 38, wherein
- 14 the second core layer is formed on the first core layer
- 15 and wherein the first core layer is formed on the
- 16 substrate.
- 17
- 18 40. A method as claimed in any of Claims 30 to 39, wherein
- 19 the first core layer is formed on the second core layer
- 20 and said second core layer is formed on the substrate.
- 21
- 22 41. A method as claimed in Claim 39, wherein a further
- 23 first core layer is formed on the second core layer
- 24 such that the first core layer sandwiches the second
- 25 core layer.
- 26
- 27 42. A method as claimed in any of Claims 30 to 41, wherein
- 28 the steps of forming any one of the substrate, first
- 29 core layer, the second core layer, and the upper
- 30 cladding layer comprise the steps of:
- 31 depositing each layer; and
- 32 at least partially consolidating each layer.



- 1
- 2 43. A method as claimed in Claim 42, wherein any one of the
- 3 substrate, the first core layer, the second core layer
- 4 and the upper cladding layer partially consolidated
- 5 after deposition is fully consolidated with the full
- 6 consolidation of any other of the first core layer, the
- 7 second core layer or the upper cladding layer.
- 8
- 9 44. A method as claimed in any of Claims 30 to 43, wherein
- 10 the formation of the substrate includes the doping of
- 11 the substrate with a dopant.
- 12
- 13 45. A method as claimed in any of Claims 30 to 44, wherein
- 14 the dopant includes dopant ions.
- 15
- 16 46. A method as claimed in Claim 44 or Claim 45, wherein
- 17 the substrate dopant includes a mobile dopant.
- 18
- 19 47. A method as claimed in Claim 45 or Claim 46, wherein
- 20 said first core layer dopant ions include tin and/or
- 21 cerium and/or sodium.
- 22
- 23 48. A method as claimed in any of Claims 45 to 47, wherein
- 24 said second core layer dopant ions include a rare earth
- 25 and/or a heavy metal and/or compounds thereof.
- 26
- 27 49. A method as claimed in Claim 48, wherein said rare
- 28 earth is Erbium and/or Neodymium.
- 29
- 30 50. A method as claimed in any of Claims 30 to 49, wherein
- 31 the concentration of the first core layer dopant is
- 32 selectively controlled during the formation of the



1 first core layer and the concentration of the second  
2 core layer dopant is selectively controlled during the  
3 formation of the second core layer so that the  
4 refractive index of the first core layer and the  
5 refractive index of the second core layer are  
6 substantially equal.

7

8 51. A method as claimed in Claim 50, wherein the  
9 concentrations of the first core layer dopant and  
10 second core layer dopant are controlled to give a  
11 refractive index for the waveguide core which differs  
12 from that of the substrate layer by at least 0.05%.

13

14 52. A method as claimed in any of Claims 34 to 51, wherein  
15 said lower cladding layer and said buffer layer are  
16 formed substantially in the same step.

17

18 53. A method as claimed in any of Claims 42 to 52, wherein  
19 at least one of the substrate, the first core layer,  
20 the second core layer, and the upper cladding layer is  
21 deposited by a Flame Hydrolysis Deposition process  
22 and/or Chemical Vapour Deposition process.

23

24 54. A method as claimed in Claim 53, wherein the Chemical  
25 Vapour Deposition process is a Low Pressure Chemical  
26 Vapour Deposition process or a Plasma Enhanced Chemical  
27 Vapour Deposition process.

28

29 55. A method as claimed in any of Claims 42 to 54,  
30 wherein the consolidation is by fusing using a Flame  
31 Hydrolysis Deposition burner.

32



- 1 56. A method as claimed in any of Claims 42 to 55, wherein  
2 the consolidation is by fusing in a furnace.  
3
- 4 57. A method as claimed in Claim 55 or Claim 56, wherein  
5 the step of fusing the lower cladding layer and the  
6 step of fusing the first core layer and/or the second  
7 core layer are performed simultaneously.  
8
- 9 58. A method as claimed in any of Claims 30 to 57, wherein  
10 the waveguide core is formed from the first core layer  
11 and the second core layer using a dry etching technique  
12 and/or a photolithographic technique and/or a  
13 mechanical sawing process.  
14
- 15 59. A method as claimed in Claim 58, wherein the dry  
16 etching technique comprises a reactive ion etching  
17 process and/or a plasma etching process and/or an ion  
18 milling process.  
19
- 20 60. A method as claimed in any of Claims 30 to 59, wherein  
21 the waveguide core formed from the first core layer and  
22 the second core layer is square or rectangular in  
23 cross-section.  
24
- 25 61. A method according to any of Claims 30 to 60, wherein  
26 the first core layer is doped with at least 17%wt  
27 germanium dopant.  
28
- 29 62. A laser waveguide with multiple core layers for  
30 transmitting an optical signal, the laser waveguide  
31 comprising a waveguide as claimed in any of claims 1 to  
32 29, the laser waveguide further comprising:



1 at least one grating formed in said waveguide core.

2

3 63. A laser waveguide as claimed in Claim 62, wherein the

4 laser waveguide further comprises at least one optical

5 interference mirror.

6

7 64. A laser waveguide as claimed in Claim 63, wherein

8 the optical interference mirror is provided at the

9 input of the waveguide.

10

11 65. A laser waveguide as claimed in Claim 64, wherein the

12 interference mirror is butt-coupled to or directly

13 deposited at the input of the waveguide.

14

15 66. A laser waveguide as claimed in any of Claims 62 to 65,

16 wherein the laser waveguide includes two mirrors and a

17 grating.

18

19 67. A laser waveguide as claimed in any of Claims 62 to 65,

20 wherein the laser waveguide includes one mirror and two

21 gratings.

22

23 68. A laser waveguide as claimed in Claim 62, wherein the

24 laser waveguide includes three gratings.

25

26 69. A laser waveguide as claimed in any of Claims 62 to 68,

27 wherein the grating formed is a Bragg grating.

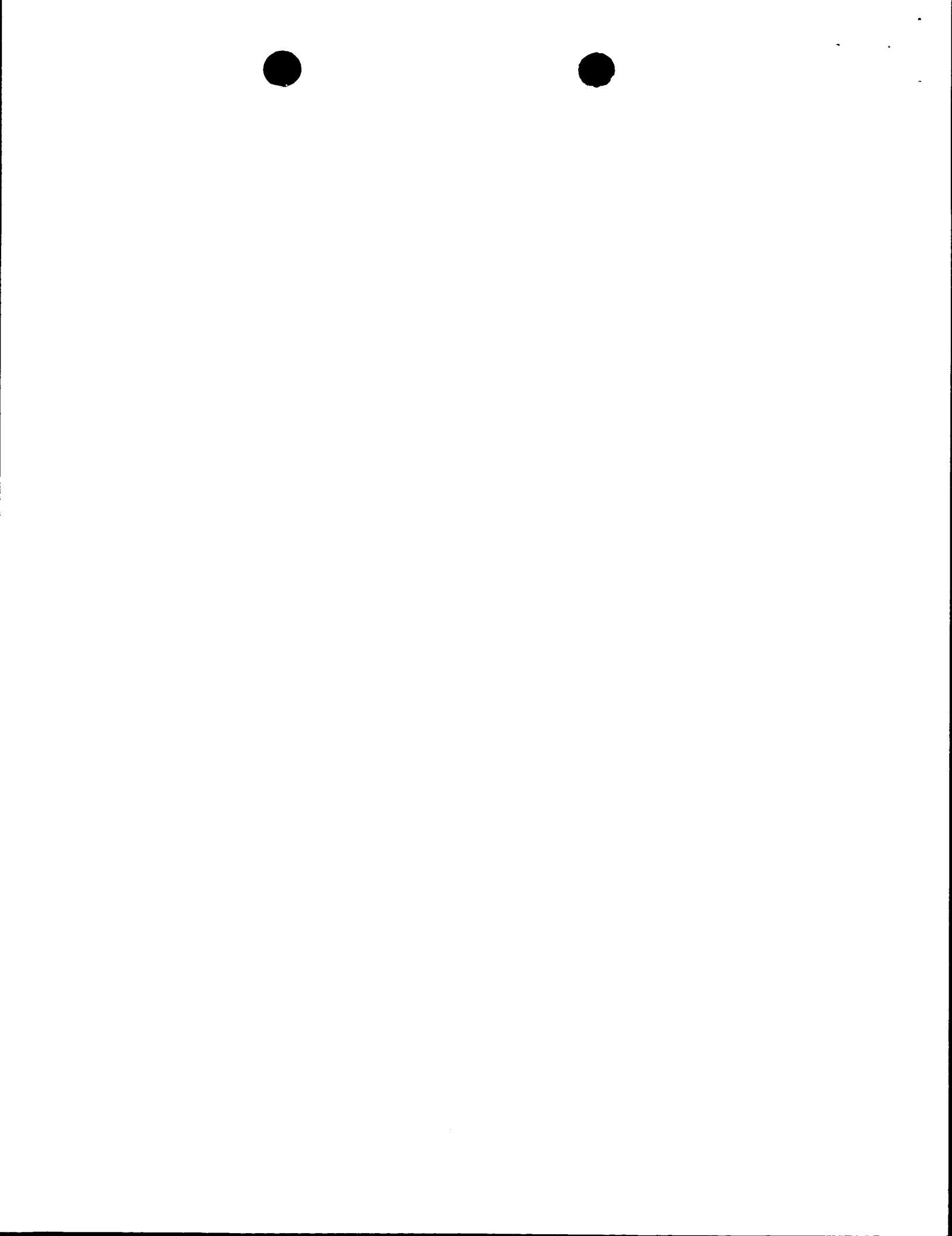
28

29 70. A laser waveguide as claimed in any of Claims 62 to 69,

30 wherein said grating forms an output coupler for said

31 laser waveguide.

32



- 1 71. A laser waveguide as claimed in any of Claims 62 to 70  
2 further comprising an optical interference mirror butt  
3 coupled to or directly deposited at the output of the  
4 waveguide.
- 5
- 6 72. A method of fabricating a laser waveguide, comprising  
7 forming a waveguide according to a method as claimed in  
8 any of Claims 30 to 61, the method of fabricating the  
9 laser waveguide further including the steps of:  
10 forming at least one grating in said waveguide core.
- 11
- 12 73. A method as claimed in Claim 72, further including the  
13 step of attaching at least one optical interference  
14 mirror to the waveguide.
- 15
- 16 74. A method as claimed in Claim 73, wherein the optical  
17 interference mirror is attached to an input of the  
18 waveguide.
- 19
- 20 75. A method as claimed in any of Claims 72 to 74, wherein  
21 the grating is formed using a laser operating at a  
22 wavelength in the range of 150 nm to 400 nm through a  
23 phase mask deposited on top of said upper cladding  
24 layer of the waveguide.
- 25
- 26 76. A method as claimed in Claim 75, wherein said mask is a  
27 quartz mask.
- 28
- 29 77. A method as claimed in any of Claims 72 to 74, wherein  
30 the grating is formed using a using an interference  
31 side writing technique.
- 32



29A

- 1 78. A method as claimed in any of Claims 72 to 74, wherein  
2 the grating is formed using a direct writing technique.  
3
- 4 79. A method as claimed in any of Claims 72 to 78, wherein  
5 the grating formed is a Bragg grating.  
6
- 7 80. A method as claimed in any of Claims 73 to 79, wherein  
8 the optical interference mirror is butt-coupled to or  
9 directly deposited at the input of the waveguide.  
10
- 11 81. A method as claimed in any of Claims 72 to 79, further  
12 comprising the step of attaching a second optical  
13 interference mirror to the output of the waveguide.  
14
- 15 82. A waveguide substantially as described herein and with  
16 reference to Figs. 1A to 1C of the accompanying  
17 drawings.  
18
- 19 83. A laser waveguide substantially as described herein and  
20 with reference to Figs. 2A and 2B of the accompanying  
21 drawings.  
22
- 23 84. A method of fabricating a waveguide with multiple core  
24 layers substantially as described herein and with  
25 reference to Figs. 1A to 1C of the accompanying  
26 drawings.  
27
- 28 85. A method of fabricating a laser waveguide with multiple  
29 core layers substantially as described herein and with  
30 reference to Figs. 2A and 2B of the accompanying  
31 drawings.  
32

